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ABSTRACT

The Governors' Task Force on Technology focused on the development of policies and programs that encourage effective use of technology in the classroom. Part one of this document lists the charges to the task force to investigate the most cost-effective ways to use various technological advances, and to consider policy questions. Task force hearings and presenters are also listed. Part two consists of two papers: (1) "Making Effective Educational Use of Advanced Technology" (Cindy K. Currence); and (2) "Policy Recommendations for Developing Appropriate Uses of Technology in Schools (Stanley Pogrow). Part three cites highlights of current state programs and additional information sources. (JD)

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TASK FORCE ON TECHNOLOGY

Supporting Works

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Time For Results

THE GOVERNORS' 1991 REPORT ON EDUCATION

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TIME FOR RESULTS: The Governors' 1991 Report on Education

Supporting Works

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August 1986.

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The National Governors' Association Center for Policy Research and Analysis coordinated the year-long project. Professional staff and consultants include Joe Nathan, Joan L. Wills, Evelyn Ganzglass, Carol Eliason, Stanley Pogrow, Rae Young Bond, Linda Myers Dove, Jean McDonald, and Cindy K. Currence. Editorial support was provided by Mark Miller, Karen Eldridge, Diane Greene, and Alan Janesch. Expert secretarial assistance was provided by Beverly Bowers, Linda Burnette, Luisa Farrell, Francine Matthews, and Deborah Woods.

The Task Force on Educational Technology of the National Governors' Association received the cooperation of many individuals who shared their expertise and knowledge at the task force hearings and in written testimony. Dr. Charles Haughey and Jim Bencivenga of the Office of Educational Research and Improvement (OERI), U.S. Department of Education were supportive of this effort and the OERI staff gave invaluable aid. Funding from the Lyndhurst Foundation and the Carnegie Corporation of New York made this work possible.

Charge to the Task Force on Educational Technology

The Task Force on Educational Technology was charged with gathering research, reviewing literature, and collecting testimony to address the following questions:

A. What are the most cost-effective ways to use various technological advances to:

   1. Improve educational opportunities for children, with particular emphasis for those in remote areas;

   2. Increase administrators' effectiveness;

   3. Increase learning for most students?

B. What are the implications for state policies of the rapid pace of technological innovation? How should this affect state policies on:

   1. Purchase of equipment and instructional materials;

   2. Instruction;

   3. Training programs for prospective teachers and administrators?

C. What kinds of cooperation with vendors have states found to be most useful?

D. What evidence is available about the value of training programs established by different groups?

E. What is known about the effectiveness of instruction delivered via television, radio, videotape, or computer compared to that directly delivered by teachers in classrooms? What have states done to maintain quality control for high school or college students who seek credit for such courses?

F. What kinds of technology-related skills will be required of workers in the twenty-first century?

In addition, the task force was asked to consider these policy questions:

A. How can states encourage attention to, and use of, other technologies in addition to computers? How can states encourage coordinated, rather than isolated, use of technology?

B. What planning should states require of each district using advanced technology? What incentives and assistance should states provide for planning programs?

C. What kind of course and competency requirements do states wish to adopt for students, prospective and current teachers?

D. What technologically-related training opportunities for administrators and teachers do states wish to establish? What kinds of monitoring should be done? What, if any, controls should be put on training programs established by corporations producing various technologies?

E. What steps could a state take to increase equal educational technology opportunities for students? Should states target assistance to specific regions, such as rural or low income urban areas?

F. What are appropriate roles for states to produce and evaluate instructional materials for advanced technology?

G. What public-private partnerships in educational technology could states encourage?

H. What are the implications for state policies on vocational education of jobs being created and threatened by technological advances?

I. What can states do to retain skills of outstanding faculty who are being offered jobs outside of school?

J. What arrangements should states make to provide credit for and assess the quality of learning gained via various technologies?

Task Force Activities: Hearings And Presenters

The Task Force on Educational Technology held three hearings, all in Washington, D.C. Witnesses at the first hearing represented the research community, state officials and national education groups. The major topic under consideration was the uses of technology for educational purposes.

Washington, D.C., January 10, 1986

Henry Becker
Johns Hopkins University
Baltimore, Md.

Frank Fisher
Urban Institute
Washington, D.C.

Geoffrey Fletcher
Education Technology Office
Texas Education Agency

Orbry Holden
Executive Director
Texas Association of School Boards
(representing the National School Boards Association)

Margaret Lathlene
National Aeronautics and Space Administration
Teacher in Space Program
Friends Wood, Texas

Gary Marx
Associate Executive Director of Communication
American Association of School Administrators

J.R. Pennington
Apple Computer, Inc.
Atlanta, Ga.
(for the National Association of Secondary School Principals)

Linda Roberts
Congressional Office of Technology Assessment
Washington, D.C.

Marc Tucker
Executive Director
Carnegie Forum on Education and the Economy

Gilbert Valdez
Manager, Curriculum and Technology Section
Minnesota Department of Education
St. Paul, Minn.

Gary Watts
Assistant Executive Director
National Education Association
Washington, D.C.

The second hearing focused on cost-effective ways to utilize educational technology from the perspective of the federal government.

Washington, D.C., February 22, 1986

William H. Booz
Special Project Teacher, Office of Instructional Technology
Fairfax County, Va., Public Schools

George J. Nolfi
Senior Management Analyst, Education and Training
Office of the Secretary
U.S. Department of Defense
Washington, D.C.

Karen Sheingold
Professor, Bank Street College of Education
Director, Center for Children and Technology

Frank Withrow
Team Leader, Technology Application Group
Office of Educational Research Improvement
U.S. Department of Education
Washington, D.C.

A variety of topics were covered at the final hearing. A panel of Virginia educators discussed Virginia's comprehensive technology program. Television as a technological tool for educational purposes was considered by a panel of specialists. A corporate roundtable discussion centered on educational technology software. A variety of other witnesses addressed issues such as computer use in education, interactive videodiscs and microcomputers in education, and state and local educational technology programs.

Washington, D.C., April 8, 1986

Ron Anderson
Technology Instructor, Thomas Jefferson High School for Science and Technology
Fairfax County, Va., Public Schools

Frank Barber
Director of Instructional Computing
DeKalb County, Ga., Public Schools

William A. Beasley
Co-chairman, Computer and Technology Committee
National Association for Gifted Children

Charles Blaschke
President
Education Turnkey Systems, Inc.

Douglas Bodwell
Director of Education
Corporation for Public Broadcasting

Elsie L. Brumback
Assistant State Superintendent for Media and Technology
North Carolina Department of Public Instruction

Edwin G. Cohen
Executive Director
Agency for Instructional Technology

Juanita Edgerton
Business Teacher
Walbrook Senior High School
Baltimore, Md.

Donald Finley
Secretary, Virginia Department of Education

Sandy Greenberg
Teacher
Glen Cove, Long Island, N.Y.

George L. Hall
Executive Director
Interactive Videodisc Consortium

Richard Jonsen
Deputy Director
Western Interstate Commission for Higher Education

Charlotte LeGates
Director of Communications
Computer and Business Equipment Manufacturers Association

Keith W. Mielke
Vice President for Research
Children's Television Workshop

J. Michael Mullen
Associate Director, Council of Higher Education
Commonwealth of Virginia

Terri Rosenblatt
Executive Director
Teacher in Space Foundation

David E. Sawyer
Assistant Superintendent
Fairfax County, Va., Public Schools

Judah Schwartz
Visiting Professor of Education
Co-director, Educational Technology Center
Harvard Graduate School of Education

Ken Wasch
Founder
Software Manufacturers Association

Sandra H. Welch
Deputy Executive Director
Kentucky Educational Television

PART TWO: Papers

MAKING EFFECTIVE EDUCATIONAL USE OF ADVANCED TECHNOLOGY

Prepared by Cindy K. Currence
Consultant
National Governors' Association

THE PROBLEM

The demand for highly skilled workers in new fields is accelerating rapidly, reports the National Commission on Excellence in Education (1983). For example, computers and computer-controlled equipment are penetrating every aspect of our lives -- homes, factories, offices, et cetera. One estimate indicates that by the turn of the century, million of jobs will involve laser technology and robotics. Technology is radically transforming a host of other occupations, including health care, medical science, energy production, food processing, construction, and the building, repair, and maintenance of sophisticated scientific, educational, military, and industrial equipment.

The scientists and engineers who will provide the new knowledge and ideas required to maintain our world leadership will need increasingly sophisticated education in science and mathematics. Many others must be given the background necessary to build, maintain, and use the technological devices that are increasingly permeating business and industry.

Yet we appear to be raising a generation of Americans largely lacking the understanding and skills to participate fully in the technological world in which they live and work (National Commission on Excellence in Education 1983). For example:

- o International comparisons of student achievement reveal that on nineteen academic tests American students were never first or second and, in comparison with other industrialized nations, were last seven times.

- o Average achievement of high school students on most standardized tests is now lower than twenty-six years ago when Sputnik was launched.

- o More than half of the population of gifted students do not match their tested ability with comparable achievement in school.

- o Many seventeen-year-olds do not possess the "higher order" intellectual skills we should expect of them. Nearly 40 percent cannot draw inferences from written material; only one-fifth can write a persuasive essay; and only one-third can solve mathematics problems involving several steps.

- o There was a steady decline in science achievement scores of U.S. seventeen-year-olds as measured by national assessments of science in 1969, 1973, and 1977.

- o Between 1975 and 1980, remedial mathematics courses in public four-year colleges increased by 72 percent and now constitute one-quarter of all mathematics courses taught in those institutions.

This paper reviews literature and research on technology, synthesizes the testimony presented at the three hearings on technology, and presents models of state activities and programs.

Analysts examining these indicators of student performance and demands for new skills have made some chilling observations. Paul Hurd (1983) concluded at the end of a thorough national survey of student achievement that within the context of the modern scientific revolution, "We are raising a new generation of Americans that is scientifically and technologically illiterate" (National Commission on Excellence in Education). The National Science Foundation has warned of "a growing chasm between a small scientific and technological elite and a citizenry ill informed, indeed uninformed, on issues with a science component.

Such reports have led many state legislatures and boards of education to institute within the past three years "computer literacy" requirements and increased mathematics and science requirements as part of their educational reform packages (Education Week 1985). Last year, California passed a law requiring three years of math, two years of science, and at least one additional semester of computer science for all high school graduates. Included in this legislation were funds to establish nineteen regional computer centers whose primary function is to progressively retrain the state's 175,000 teachers. Texas, West Virginia, Pennsylvania, Tennessee, Florida, New York, and twelve other states now are planning similar, sweeping mandatory changes in curriculum inservice training and computer facilitation (Career Training 1986).

Educational technologies such as radio, motion pictures, television, video cassettes, video disks, and most recently, computers, have been viewed as bringing experiences beyond the child's daily life into the classroom. They combine the best of pedagogy and theater, and provide a basis for creative interactions between students and subject matter. They have been viewed as possible solutions to the rising costs of education as the capital investment of technology is substituted for labor (Jamison, Klees, and Wells 1978; Wagner 1982). They also have been characterized as an almost infinite means to educational experiences, limited only by the vision of those who apply the technologies to instruction and by the imagination of the student (Levin and Meister 1985).

The high hopes educators and policymakers hold for the use of technology in education are evidenced in a report from the U.S. Education Department's Office of Educational Research and Improvement (OERI 1983):

> The computer is a one-in-several centuries innovation. The low cost and wide availability of the computer, combined with other technological and scientific advances, are changing the nature of business, industry, and everyday life.
>
> Preparing students for this new world makes strong demands on education, at a time when the cost of education is rising more rapidly than other prices.
>
> Fortunately, the computer, combined with new knowledge of human thinking and learning, provides new means for meeting these needs and eventually for increasing the productivity of education.

The computer, interactive video, and other new information technologies hold promise of "dramatic" improvements in learning. F.D. Fisher (1986) states: "With a big increase over present efforts to develop the new technologies for educational use, we might achieve within two decades something like a one-sixth improvement in mastery of what is learned, a one-sixth acceleration in learning, and a reduction of one-sixth in the teacher/pupil ratio -- altogether, a 70 percent increase in teacher productivity."

As a result, according to Fisher, teachers could receive higher pay, 50 percent more students could study the subjects of higher education, and disadvantaged learners could receive individual attention.

Lipson and Fisher (1984) conclude that "the computer and the videodisc technologies will prove to be the most valuable teachers' aides ever invented."

Research, in general, supports these high hopes for the new educational technologies, particularly the use of computers as instructional tools. J. Kulik (1983) found in a review of fifty-one studies that students who received computer-assisted instruction (CAI) scored better on objective tests than students who received traditional instruction only. To put it statistically: If all the children in all fifty-one studies reviewed by Kulik had taken the same norm-reference test, the average student not receiving CAI would have scored at the fiftieth percentile while the average student receiving CAI would have scored at the sixty-third percentile. The average student receiving CAI, then, would have scored better than sixty-three out of every 100 students taking the test. Kulik's research also reveals two other significant results: CAI improved retention when students were tested at some time after the CAI program had ended, and CAI can improve the speed at which students learn a given amount of material.

But achievement outcomes are not the whole story. In the area of affective/motivational outcomes of CAI, the news is almost as good. At the college, high school, and elementary school levels, students have good things to say about learning from computers. Students consistently report they enjoy moving at their own pace and the lack of embarrassment about mistakes. Research suggests that anything that enhances a child's feeling of being in control of his or her destiny is generally beneficial (Bracey 1982).

A recent study of cost-effectiveness of CAI gives it high marks, finding that a "drill and practice" CAI curriculum is considerably more cost-effective in increasing reading and mathematics achievement at the elementary school level than either reducing class size or increasing the length of the school day (Levin, Glass, and Meister 1984).

Such outcomes have encouraged examination of the use of computers and advanced technology in the classroom. Artificial intelligence research already has resulted in several versions of a computer tutor (OERI 1983). These systems have expert knowledge about subject matter, can diagnose the level of a student's knowledge, and have strategies for tutoring the student to higher level of understanding and skill. One system can improve students'

play in a game that requires construction of arithmetic expressions; another coaches troubleshooting of an electronic circuit; a third provides help in writing. Computers can be a powerful intellectual tool and media of expression for students.

Given an adequate analysis of human cognitive processes, computers also can be programmed to quickly ascertain a student's existing knowledge, understanding, and misconceptions. Computer diagnosis can make teachers more aware of the ways in which procedural skill and conceptual knowledge combine to produce good performance. Computers can show deficient components in any student and help teachers become aware of areas in which their students need further work. Better tools for diagnosis, properly used, can help raise the goals of education from finishing textbooks and passing tests to achieving powerful intellectual skills that can be applied in real world settings.

Another common use of computers and interactive video technology in schools is creating simulated laboratories and games. This technology can be used to simulate, through animated displays, a variety of phenomena from which students can learn. These include both the laboratory exercises already in use and activities that would be impossible to conduct with real materials. There are a number of advantages to such simulations. They may be cheaper, since no special equipment beyond the computer system itself is required for any given simulation. They can operate on different time scales, allowing exploration of processes that occur too quickly in real life or that take so long that they are incompatible with the pace of schooling. Similarly, size is no barrier; it is as easy to simulate events inside a molecule or events involving an entire galaxy as it is to simulate something that one could see out the classroom window. Simulated events cause no physical harm, while many important laboratory demonstrations can be dangerous.

Adding to the attractiveness of these technologies is their rapidly falling costs. The first dedicated computer used for instruction in a school cost a third of $1 million. Today, current systems with good graphics cost about $1,000, and it appears likely, projecting trends in hardware and software technologies, that computational power equivalent to that of present day super computers will be available in a microprocessor system for less than $100 by 1990 (OERI 1983).

It is hardly surprising, then, that the most recent statistics indicate that the use of computers in schools is widespread and growing. Schools bought a record number of computers during the 1983-84 school year (Market Data Retrieval 1985). By the fall of 1984, officials of 69,003 public schools reported using a total of 570,000 microcomputers for instruction, up from 325,000 the previous fall. The Market Data Retrieval survey found that the increases in computer usage were not limited to a particular segment of the field but occurred across the board -- in public and private schools, in elementary and secondary schools, and in both affluent and poor schools. The survey also found that 85.1 percent of the nation's public schools reported using at least one microcomputer for instructional purposes. That represents an increase from 68.4 percent of schools in 1983, 30 percent in 1982, and 18.2 percent in 1981.

However, the rush to purchase computers and other new technologies and the rapid expansion of computer use concern many experts. Their concern stems from several factors:

- Other advanced technologies -- starting with the radio and continuing with television, videotape recorders, language laboratories, teaching machines, and even overhead projectors -- have had relatively little impact on the nation's public schools, despite their "promise" as a tool for improvement;
- Research indicates that many school districts have not done careful planning before purchasing computers;
- The teacher training needed to successfully implement a new technology program frequently is inadequate;
- Current use of computers in educational settings raises serious equity and access issues for females and minorities; and
- Experts disagree about the most valuable ways to use machines to increase students' learning in cost-effective ways.

FAILED PROMISES

Advanced technologies developed during the past fifty years have consistently held out promise for educational use. The U.S. Commissioner of Education in 1932 said the radio would "stimulate a new revival of learning." In 1962, the education editor of The New York Times wrote that teaching machines and programmed learning could "revolutionize teaching methods" and had "tremendous potentialities to improve American education."

Such claims have been made about (and millions of dollars spent on) radio, television, overhead projectors, videotape recorders, motion pictures, talking typewriters, and language labs. Conferences have been held, training programs created, magazines started, articles and books written, federal and foundation money spent. Yet these machines have had little impact on actual learning and teaching in schools (Nathan 1985; Levin and Meister 1985).

Similar hopes have been pinned on today's technology, but in practice, no educational technology -- including CAI -- has come close to fulfilling its promise on a systematic or sustained basis (Levin and Meister 1985). Some of the blame for this failure has been placed on teachers who have been deemed inflexible, resistant to innovation, and opposed to technology on the grounds that it would undermine their livelihood (Cuban 1984). In other cases, the technologies themselves have been faulted. For example, because educational radio delivered only audio instruction, it was handicapped in the teaching of written material. Although film surmounted this obstacle by integrating sight and sound, use of the medium was particularly cumbersome. It required large numbers of movie reels for even a single course as well as projectors for each classroom and substantial personnel time for the mechanics of showing and rewinding lengthy reels.

With the advent of instructional television, many of these objections were overcome. Closed-circuit television enabled the transmission of lectures or films and tapes from a central studio with the flexible capability to reach a single classroom, many classrooms within a school, or the classrooms of an entire school district. Broadcast television could reach even further, to hundreds or thousands of schools and millions of households with a single program. Many schools purchased television sets and studio facilities to provide instruction, but this medium, too, never fulfilled its promise (Cuban 1985). One technical obstacle that was identified for the failure of instructional television was its highly centralized transmission requirements that meant its economical use required large numbers of classrooms or homes to accommodate relatively rigid broadcasting schedules. In addition, preparation of high quality programming took considerable planning, talent, and funding -- resources that were not sufficiently available to schools or economically palatable to networks and sponsors. Software issues such as the adequacy of commercially available materials also inhibited the success of instructional television, as with film.

By the early 1970s, closed circuit and other forms of instructional television had largely yielded to the more decentralized technologies of videotape and videocassette approaches. These formats overcame many of the earlier obstacles of instructional television because schools, teachers, and students could create their own instructional materials with relatively little experience. Further, there was a high level of flexibility in the use of this medium, since videotaped instruction could be used in individual classrooms or multiple classrooms or by individual learners as needed, without conformity to a broadcasting schedule. Finally, there was great simplicity in the operation of the equipment. Most schools had obtained the videocassette equipment by the late 1970s, yet it was rarely used systematically for instruction (Levin and Meister 1985).

Whether computers and other advanced technologies of today will live up to expectations largely depends on whether schools effect institutional changes to foster the use of advanced technology for educational purposes. Stanley Pogrow (1982) is optimistic that today's technologies will not end up in the closet, as others have. According to Pogrow, "History suggests that a technology will play a central role in the public schools if -- and when -- it first gains cultural acceptance (i.e., admittance to a large number of homes) and becomes a primary work tool. The first factor reduces opposition to the introduction of a particular technology into the schools; the second factor generates public demand that the schools adopt the technology and provide training in its use." Pogrow predicts that these two criteria will be met in this decade, when 10 percent of all U.S. households have microcomputers and when 25 percent of all jobs utilize microcomputers as the primary work tool.

But H.M. Levin and Gail Meister predict that the fate of older technologies awaits today's technologies unless "we recognize the generic causes of the failure and respond to them."

THE IMPORTANCE OF PLANNING

Researchers have identified planning as one of the essential elements of successful implementation of high technology programs. School districts,

however, are handicapped by the decentralized decisionmaking and numerous decision mechanisms characteristic of the institutions (Levin and Meister 1985).

A survey conducted by the American Association of School Administrators (1984) found that few districts did comprehensive planning prior to implementation of CAI programs: only 5 percent of the respondents said their board had adopted a policy on computer education; only 10 percent said their district had adopted formal guidelines to integrate instructional computing into the curriculum; and about 80 percent said their district did not have a long-range plan for computers.

Yet experts in educational technology suggest that "planning is everything" (Neill 1984). Most planning experts advise districts to have a plan and determine specifically what they want to do before buying hardware. Unfortunately, the reverse has occurred in many school districts, so the process for schools must be somewhat more "fluid" (Neill 1984).

The Minnesota Department of Education developed a guidebook, Planning for Education Technology, for schools to use in implementing advanced technology programs. The state legislature in 1983 adopted a bill to promote formal, comprehensive district-level planning for the use of technology, including but not limited to microcomputers. In addition to the guidebook, each district was given a minimum of $500 to use for planning.

Model guidelines, such as Minnesota's Planning for Education Technology and the New York State Education Department's planning manual, Getting Started: Planning and Implementing Computer Instruction in the Schools, suggest a "staged" implementation program.

One of the first steps in an educational technology program is assessing the current situation in the district or school. The Minnesota guidebook advises that an assessment of technology is no different from an assessment of any other type of curriculum material or program. The guidebook suggests that districts answer some of the following questions in their assessment effort:

- What educational technologies are currently being used?
- How much educational technology hardware is currently available?
- Where is the educational technology hardware located?
- What are the present applications of technology in each of the following: instruction, administration, classroom management, other?
- What skills do the staff have with the present technology?
- What staff development opportunities are available?
- Is there a curriculum guide with an appropriate scope and sequence in the major subject areas?

- Is there a written plan with guidelines for implementation of technology?
- Are there advisory committees that are community based as well as staff based to provide an overall support network for technology?
- Is there one individual responsible for implementation of the overall technology program in the district?

The second stop in planning, according to the Minnesota guidebook, is developing a statement of philosophy. Such a statement should explain the motivation that led the district into involvement with technology, describe the assumptions and beliefs upon which the plan is built, and suggest the general results that the plan is designed to produce. The philosophy statement is necessary to provide direction and focus to district efforts, to communicate current thinking of district decisionmakers to all constituents, and to develop a broad base of support among staff and community. A sample statement of philosophy from the Boonton Township (New Jersey) Public Schools reads:

> The study of computers is a relevant and appropriate topic for the elementary curriculum because of the numerous applications computers have and will have in society. Children will learn to use computers in a masterful way, and, in learning to use computers, can shape the way they learn everything else. In using the computer as a problem-solving tool, children embark on an exploration about how they themselves think. Developing an understanding and appreciation for the workings of a computer and how to benefit from its use are ever increasing needs in a society today and in the future.
>
> Our approach should be to expand the existing curriculum to reflect the role that computers best play in problem solving. This means we should decrease the emphasis upon the routine and rote methods of carrying out a plan to solve a problem and increase our emphasis on analytical thinking techniques: logic, thinking, interpreting symbolic, language, and applying results.
>
> The microcomputer is a tool that will be as commonplace as a slide rule was two decades ago and as pocket calculators and pencils are today. It is essential that it becomes an integral part of current education.

The next step in the process, according to the planning research, is defining the plan in broad, general terms in order to provide guidance and general direction to those who implement the plan. The Minnesota guidebook suggests that districts also develop objectives and activities to define more precisely how each goal will be met. For example, if one of the district goals is to teach students about the impact of technology on society, the goal might be stated this way: Students will describe how the increased speed of

transportation and communication since the eighteenth century have changed the nature of the U.S. political system. The corresponding objective might be stated this way: Students can describe how global electronic communications have influenced U.S. politics over the past decades.

Next, planners must move from ideal considerations to realistic expectations in light of these factors: personnel; equipment purchases and deployment; materials selection and acquisition; and staff development, budget, and timeliness.

In general, the Minnesota guidebook advises, the most important aspect of this phase of the plan is a realistic assessment of available resources. Most plans, it adds, will call for change to occur over a period of time. Therefore, while district planners should think ahead a few years in constructing a plan, at the same time they should realize the need for flexibility as changes occur.

The final step for planners is evaluating the program through periodic measurement of progress in meeting established goals. Based on this evaluation, planners should review and revise their technology programs, the research concludes (Neill 1984). "Computer educators should be prepared; as a recent computing magazine warned, 'Computer evaluation cometh.' For many, this phrase conjures up a threatening image: narrow-minded evaluators with little sensitivity distorting the delicate successes of computer-using teachers. Yet ... an evaluation can help computer educators improve programs and learn to use modern technology in its most effective manner. One must learn to make the process work for program improvement" (Stecher 1985).

Shirley Boes Neill's research (1984) led to the following suggestions for administrators in developing technology programs:

- Build a wide base for decisionmaking about the use of technology. Students, parents, teachers (in all areas, not just math and science), and building administrators all are good candidates for advisory committees to consider issues and make recommendations.

- Hire a coordinator of technology applications.

- Don't expect or require an outside consultant to make decisions that should be made within the district.

- Consider planning as an evolutionary process that proceeds in phases. Following is the usual order: tooling up with hardware, software, and early computer training at all levels; planning as it relates to goals; and integrating computers into the curriculum.

- Plan instructional applications rather than technological applications.

- Plan to tailor the program to the school it serves, in terms of the goals to be met, the school enrollment, the budgetary restrictions, and the commitment and participation of the staff.

- Relate the planning effort to significant concerns for long-term improvement in both teaching and learning, rather than short-term improvements.

- Prepare to work with a plan through four stages: initiation, support, implementation, and revision.

- Provide adequate resources for planning. Avoid frustration by allowing for adequate time, materials, space, expertise, and money.

- Expect over time to increase budget allotments for inservice education, teacher support (materials and personnel), software, and maintenance.

- Look at model programs. However, in most cases programs must be adapted to each individual school system.

- Maintain the technology committee as an ongoing, working group.

- Involve parents and the community in the technology program.

SOFTWARE

In addition to planning, the availability and quality of today's educational software raises serious questions about whether instructional computing will live up to its promise.

The Educational Products Information Exchange Institute (EPIE) has discovered "some dismaying facts about the state of the educational software market" (1984, p. 1). EPIE research suggests that contrary to predictions that educational software would benefit from a maturing software industry, the marketplace continues to respond to a set of unexamined expectations such as: "Kids will respond to computers more enthusiastically than to workbooks, textbooks, even to books in general"; and "The software industry is new. Understandably its products are a bit crude and overpriced. In time the quality will improve and the price will come down."

Schools, teachers, students, and parents must become much more discriminating consumers of the software products that currently define educational computing, the EPIE concludes. It is these products that will either limit the effectiveness and evolution of educational computing, or expand and help fulfill its potential.

> At present the evolution of educational computing is stalled by the 'teacher comfort factor.' Too many teachers are comfortable using software that turns computers into electronic workbooks, since workbooks -- even electronic ones -- have a reassuring familiarity. Learning how to use software that turns computers into tools for shaping critical thinking, problem-setting, and problem- solving is much less comfortable. This 'teacher comfort factor' encourages a parallel 'publisher comfort factor.' Publishers are comfortable producing and marketing such drill and practice products because

> there is a ready market for them and they are much easier and cheaper to create than materials that take on the tougher task of teaching students to think. As one publisher put it at a recent conference of educators: 'We have the ability to blaze new trails but we are not in the altruistic business. We're not going to blaze new trails if you're not willing to buy them.'
>
> Within the educational software industry, where the bottom line is the final arbiter, there is, nevertheless, a desire to produce software that would move the state-of-the-art away from the comfortable toward better quality, more challenging software products. Consumers must nurture that instinct by spending their software dollars where the trail does seem to be pushing forward (EPIE 1984, p. 4).

However, this is not happening yet, according to the EPIE research. Despite the widely held notion that the software industry is maturing, the percentage of programs meeting absolute minimum standards has increased slightly, but the percentage of programs meeting exemplary standards -- programs that deserve a place in the schools -- has not increased at all. In 1983, when EPIE software analysts carried out in-depth evaluations of a representative sample of then available educational software, the institute found that only about one out of four of the products met minimum standards of educational quality, and that fewer than five out of 100 were rated exemplary. In 1984, the institute's analysts found that one out of three programs met minimum standards, but the number of exemplary programs remained at five out of 100.

Research in the fall of 1983 also found that drill and practice programs accounted for 49 percent of the more than 5,000 available educational programs. Only 5 percent of the total could be described as simulation programs to develop skills of thinking and problem-solving. A year later, with 2,000 new products entering the market, about half were drill and practice and 5 percent were simulation programs.

A large part of the problem in the use of educational software is that demand by schools for the programs is internally disorganized and fragmented. Levin and Meister (1985) found that school personnel most often learn about software from conferences, catalogs, computer magazines or directories, and colleagues. Many teachers attempt to review software at a software library or to test it over a thirty-day preview period. One of the most reliable criteria for making software decisions was considered the recommendations of other teachers who had used the materials. The researchers found that systematic searches for software were undertaken by schools only for major projects such as provisioning a new math laboratory. What emerged from their interviews was largely a "piecemeal" process heavily dependent on individual teachers and the availability of funds at the right moment (Levin and Meister 1985, p. 16).

> Software acquisition is highly decentralized, individualistic, and variable from one situation to another. Funding sources are highly idiosyncratic. Diversity in how the hardware is configured,

whether in laboratories, libraries, or classrooms, and the diversity of instructional applications and subject matters, contribute to market fragmentation.

Political movements and professional standards have also contributed to the disarray -- one could even say anarchy -- in the use of computerized instruction. Public demand has pressed for the introduction of computers in school, but mandates for computer use have been unclear and conflicting. This leaves schools to define computer goals and curricula for themselves. At the same time, traditional professional autonomy of teachers and the lack of an organized framework for all phases of software adoption leave room for highly individualistic approaches. This chaos is somewhat tempered by collegial behavior among teachers, especially those in the same subject area, who may choose to collaborate and share software and instructional applications with fellow teachers. Unfortunately, this can also lead to the ethical dilemma of unauthorized copying of software which may be seen as legitimately helping a colleague (Levin and Meister 1985, p. 20).

Such conditions have led software firms, both those specializing in development and in publishing, to consider the market for educational software risky, unstable, and chaotic (Levin and Meister 1985). The reasons for this are many and varied. The installed base of school computers includes a large number of different brands with different operating systems and specifications. Little uniformity exists within a single school or school district. Moreover, decision processes and funding arrangement vary so substantially from setting to setting that producers cannot devise a parsimonious set of strategies to assess the market or to obtain sales. The risky nature of the market and the high cost and time requirements for software development also discourage lenders from providing the necessary capital. All of these obstacles also thwart development of high quality software that could make a profound impact on instruction.

C. Blaschke (1986) points out that unlike the textbook industry, the private sector -- including not-for-profit groups involved in developing, producing, marketing, and selling microcomputer hardware and software -- operates under a different set of incentives, has created radically different commercial patterns, and is ever changing and volatile. Traditional textbook publishers plan a life cycle of about five to seven years for a textbook, pay developers relatively low royalties, and produce large volumes to reduce cost. Electronic learning publishing, on the other hand, is characterized by high royalty payments, courseware life cycles of two years or less, low production volume and costs, and significantly higher marketing and distribution cost. In addition,

- Approximately 80 percent of all courseware produced for instructional education was developed by small to medium-sized development firms and groups, not large, traditional publishers; over time, publishers may increase in-house development activities.

- In 1983, TALMIS reported schools purchased approximately 42 percent of all courseware and 79 percent of all hardware directly from retail software and computer stores; only 13 percent of courseware was purchased through education dealers and audio-visual networks traditionally used by publishers. Today 60 to 70 percent of education software is sold through direct means (Blaschke 1986, p. 9).

Software company executives concur with Blaschke's findings. According to Marc Canter of MacroMind, Inc., "Right now there is no reason in the world why a high quality software development company would ever want to produce educational software. To put it bluntly, there's not money in it."

There are significant opportunities for applying educational technology, but the exigencies of the market may prevent these opportunities from being realized, conclude Levin and Meister (1985).

Blaschke (1986), Levin and Meister (1985), and Canter (1986) make the same general policy recommendations for improving the software situations:

- more coordinated market information;
- improved decision mechanisms in the schools; and
- large-scale institutional approaches to software development and funding. [This recommendation is particularly important in the development of appropriate software for minority populations, such as bilingual students and handicapped students (National Commission for Employment Policy 1985)].

In addition to institutional responses to the problem, software manufacturers must ensure that programs are easy to use and accompanied by clear documentation; provide opportunities for students to control the learning process; provide interaction, feedback, and rewards; allow students and/or teachers to establish goals and provide self-evaluation; allow diagnosis of conceptual difficulties with materials; use the full range of hardware capabilities; allow for easy integration into the curriculum; and include, at a minimum, student record-keeping capabilities and monitoring of student progress (Ryba and Chapman 1983, Shavelson 1984).

TEACHER TRAINING

The lack of teacher training in the use of technologies also may limit their development for educational uses, according to experts. In a survey of Nebraska teachers, 72 percent said they needed training in the use of computers. When asked to predict the future uses of computers in schools, teachers were conservative in their responses and many left the questions blank or said they didn't know (Steven 1982).

Thus, the need for training of teachers is one of the major contemporary concerns in educational computing (Hess and Miura 1984). The most significant

problem, perhaps, is that microcomputers were introduced into a profession that was not trained in their use. With computers coming into the schools through a grass-roots movements, training needs were initially not organized in a systematic way. Teachers who wanted to acquire skills followed a chain of opportunities that were fortuitous or developed by determination and effort. Tutoring by friends, by students, by colleagues, or by sales representatives was a common source of competence.

Because of the novelty of computer technology, few teachers are really prepared to integrate it into their teaching methods (Zuk and Stillwell 1984). Many teachers and staff view the introduction of technology to the classroom as antagonistic to their sense of humanistic education. Others fear they do not have the abilities or skills necessary to learn how to use computers. Computer anxiety is no myth, and, if not dealt with, can interfere with learning about computers.

Researchers found, however, that training reduces this anxiety (Jones and O'Shea 1982). As the technology has become more widely accepted and its uses more distinctly defined, training programs have taken on a more consistent shape. In California, for example, training is offered through a system of Teacher Education Computer Centers. Modules for training trainers of teacher also are prepared and distributed through the centers. In one region, the center works with the coordinator of computer education of the county to provide training modules for other centers in the state. Training programs also are offered by extension services of the University of California; private universities offer summer courses in PASCAL and workshops in programming and productivity software packages. Courses in programming, including assembly languages, computer hardware and electrical principles applicable to computing, and computing for handicapped students or preschoolers are offered by community colleges. And some districts offer their own workshops and courses.

The need for inservice training comes in part from changes in technology. The instructional staff must decide what level of obsolescence they can tolerate within the limits of their economic resources. At some point in the future, however, the level of sophistication of hardware will reach an acceptable degree of stability, and obsolescence may be a less serious problem. This is not likely to happen in the near future, even with hardware where educationally important advances are appearing (Hess and Miura 1984).

Such rapid changes suggest there will be a lengthy period of transition during which training for teachers who are new users will be offered along with continuing or periodic inservice training for teachers who already have acquired competence. Such continual training probably will increasingly be incorporated into administrative planning, with allocation of sufficient time and resources on a continuing staff development basis. Some school districts may find it feasible to develop a center for inservice updating for teachers, thus providing their own training resources. In the future, such updating may be available on line.

State leaders are taking an active role in providing teacher training. Even in states that do not specify curriculum requirements for students at the

local level, state legislatures and departments of education sometimes establish standards for teacher certification and provide inducements for teachers to get inservice training in some aspect of educational technology. By late 1983, sixteen states either required or recommended pre- or inservice training in educational uses of computers. An additional twenty states were considering proposals for such training (Hess and Miura 1984). The goal of Rhode Island, for example, is the 90 percent of all teachers will be "computer aware" in three years, of which 40 to 50 percent will be "computer literate." Only Arkansas and the District of Columbia have passed legislation that requires teachers to gain competence with computers. Seven states require preservice training -- Arkansas, the District of Columbia, Montana, New Hampshire, South Dakota, Utah, and Vermont. The level of concern is highest for teachers who offer courses in programming and "computer science." It seems likely that certification requirements soon will emerge for training such teachers (Hess and Miura 1984).

Most experts agree that staff development should be skill based, addressing some of the key problems in the use of software, e.g., integration of courseware into the curriculum (National Commission for Employment Policy 1985). Inservice programs, conducted by experienced computer-using school staff, should be relied upon more heavily than programs conducted by teacher training institutions. Although program accreditation and teacher certification may be appropriate long-range policy instruments, most experts suggest that the process of creating such instruments will be lengthy and will lack necessary flexibility, thus constraining the effective use of technology in the classroom (National Commission for Employment Policy 1985).

EQUITY ISSUES

A question of increasing concern regarding the availability and use of computers in schools is the gap between the "have's and have not's."

Advocacy groups are insisting that schools take responsibility for ensuring equity in computer use. Their concerns stem from reports that show significant differences in computer use by white and non-white low-income schools (Becker 1983). H. Becker found significantly more instruction in computer programming in low-income, majority white elementary schools that in low-income schools where most students were non-white. These schools were far more likely to use computers for drill and practice and to teach little or no computer programming. Becker attributed this finding to the fact that there are fewer "computerist teachers" in low-income schools with a majority of non-white students.

Another survey conducted by the American Association of School Administrators concluded that federal Chapter 2 funds are helping districts move into the high technology area, but that the "block grant delivery system is creating a serious equity problem. Approximately 80 percent of America's students attend schools in 24 percent of the nation's school districts" (Neill 1984). However, the report states, the large urban centers are big losers under the block grant program. "The small districts are gaining funds, but they service fewer students," the report concludes. Fifty-six percent of the districts responding to the survey said they were using their Chapter 2

allocation for 1982-83 to buy books and materials; 50 percent said computer hardware; 34 percent, computer software; and 25 percent, audiovisual equipment. Ninety-four percent of the districts said they were not funding the Energy School Aid Act (one of twenty-eight programs consolidated under Chapter 2).

R.D. Hess and I.T. Miura (1984a) found that computer "whiz kids" are rarely girls. In a survey of eighty-seven middle and upper-income students in grades five to eight, they found that 13 percent of the students -- all boys -- reported having home computers. One year later, in another poll of the original sample of students, home computer ownership had risen to 35 percent, with a two-to-one ratio of boys to girls. They also found a two-to-one ratio in favor of boys in enrollments in summer computer camps and classes.

The Project on Equal Education Rights, an equity watchdog arm of NOW, suggests eleven actions that local districts can take to open computer learning to all students.

- o Institute a computer literacy program as part of the core curriculum. Make one of the goals of the program to neutralize biased images. Encourage girls, minority boys, and disabled students to participate.

- o Make sure any training for teachers includes a focus on strategies to encourage girls, minority boys, and disabled students to participate in computer introduction and related courses.

- o For any optional courses in computer instruction, make sure that course requirements are not unnecessarily difficult and that they are clearly explained to students.

- o Review all software before purchasing to make sure it is nonbiased.

- o Structure free time on the computer and after-school computer clubs so that all students are encouraged to participate, including girls, minority boys, and disabled students.

- o Offer evening programs about computers and their impact on jobs and education for parents and families. Include discussions of equity issues so that they can learn to encourage their daughters as well as their sons to study computer science.

- o Familiarize key teachers and counselors with the impact of computers on the job market so they can talk intelligently with students about job options.

- o Develop partnerships with local businesses both to strengthen the computer-based education program and to develop a concrete understanding of local employment opportunities generated by the computer and related technology.

- o Develop recruiting strategies that encourage girls, minority boys, and disabled students to enroll in any advanced, optional courses.

- o Develop a planning committee to manage the process of designing and implementing a computer-based learning program. Infuse equity into all of the goals and objectives of this committee's work. Ask parents and community groups to participate.

- o Make sure computers are distributed equitably across schools within the district.

USING TECHNOLOGY EFFECTIVELY

Computer literacy is a rapidly changing concept defined differently by different people and interest groups. Originally conceived a decade ago as a catch-all term to include a general knowledge of the technology, computer literacy has, in recent years, become the focus of more specific and varied definitions. To this point, attempts to develop a uniform definition of computer literacy have been unsuccessful (Nathan 1985, National Commission for Employment Policy 1985).

Most experts believe the concept of computer literacy will change as education policymakers view the computer as one of several technology tools for the emerging information age (National Commission for Employment Policy 1985). Some experts also believe it would be detrimental to establish, directly or indirectly, a national definition -- or even national standards -- for computer literacy. Experts also are extremely concerned about recent attempts to include specific computer literacy items and domains on national standardized tests or other assessment tests that allow comparisons among states and among local districts within states. In the long run, they argue, national computer literacy standards and standardized testing would result in the propagation of obsolete standards as the nature of technology changes rapidly and new applications emerge.

The commission report concludes that the "only true option available to policymakers is the fostering of a comprehensive and enlightened debate on the various issues surrounding the computer literacy concept" (p. 74).

In addition to the debate about computer literacy, experts have in recent reports questioned the effectiveness of CAI. According to H.M. Levin, G.V. Glass, and G.R. Meister (1984), CAI intervention evaluated in their study was more cost-effective than adult tutoring, reducing class size, or increasing instructional time. However, it was considerably less cost-effective than peer tutoring in mathematics and slightly less cost-effective in reading. This suggests, they conclude, that CAI intervention does perform comparatively well according to cost-effective criteria, although it is not necessarily the most cost-effective approach to improving mathematics and reading achievement in the elementary grades. They add, however, that as new developments occur in CAI instruction, its relative cost-effective might improve.

Another debate raging in the research community is that of what to teach about computers in schools. Computer programming has been called the "Wheaties of the Mind," a panacea for the ambiguities of everyday cognition (Pea 1984). S. Paper (1980) suggests that use of Logo, a highly structured

computer language used in many elementary and secondary schools, can provide extensive cognitive benefits "without deliberate or organized teaching" (p. 8).

Other researchers contend that, at the present time, the evidence that learning to program develops students' problem-solving and thinking abilities is slim (Capper and Copple 1985). Evidence is mounting to suggest that the amount of time required to learn programming effectively is much more than is typically allotted in schools. R. Mawby (1985) found that students in grades eight to ten who received fifty hours of instruction in Logo showed little understanding of the control structure and variables of the language. He asserted: "Without this understanding, students cannot use the powerful Logo constructs which engage and support high level thinking skills" (p. 8).

One of the most frequently cited reasons for bringing computers to schools is the need to learn to use the computer to be competitive in the job market. H. Goldstein and B. S. Fraser (1985) looked at the need for computer skills in the workforce and concluded: "Although computer use is widespread and growing rapidly, relatively few workers need extensive education or training in computer-related skills; most learn their skills in brief, on-the-job training. Young workers need not fear being frozen out of the job market because they have not learned about computers" (p. 1).

Goldstein and Fraser estimate that only about 1 percent of the workforce will require long periods of computer training, e.g., engineers and scientists who design computers, teachers of computer science, programmers, systems analysts, and repair personnel. An additional 1 percent of the workforce will need to be able to write their own programs, e.g., some engineers, scientists, technicians, accountants; and the remaining computer users will need minimal training to learn such computer uses as word processing, information storage and retrieval, or industrial process control. These skills, the researchers found, can be acquired in short training sessions lasting from a few hours to a few weeks.

Such debate and evidence has led some researchers to conclude that it may be more important to be proficient at using the computer as a tool than to be proficient at programming. Word processing, for example, offers promise of improving many students' writing skills (Nathan 1985).

An example of this comes from the high school in Lakeville, Minnesota. For several years, students in some courses have been using word processing to help with their writing. As part of his work for an advanced degree, a teacher compared students who used word processing with those who did not. The two groups represented both sexes and various levels of ability. The teacher's first funding was that using word processing wrote significantly more than the control group as they moved from rough draft to final copy. His second finding was that the group using word processing made almost twice as many major changes in their essays as did the students who were not using computers (Mako 1985).

Joe Nathan (1985) also cautions that there can be negative results from computer use. In one study, a computer breakdown, deliberately created by researchers, occurred for some students. When students were asked what they

thought caused the breakdown, 42 percent of the students blamed themselves, 32 percent blamed themselves and the computer, and 26 percent blamed only the computer. "Thus almost 75 percent of the students said they bore some responsibility for the problem. In fact they had nothing to do with the malfunction. Equally important, this incident influenced students' views for at least six months; they were more likely than other students to think that their computers would break down" (p. 48).

Nathan concludes: "We should not accept the generalization that using computers is the most effective way to teach most subjects. It's more accurate to say that using computers can be an effective way to increase learning for some students in some subjects" (p. 50).

MAKING EFFECTIVE EDUCATIONAL USE OF ADVANCED TECHNOLOGY

Model Program Resources

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POLICY RECOMMENDATIONS FOR DEVELOPING APPROPRIATE USES OF TECHNOLOGY IN SCHOOLS

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STATEMENT BY THE AUTHOR

For the past three years I have been developing the Higher Order Thinking Skills project. This is a program that uses computers to develop the higher order thinking skills of compensatory students at the elementary level. The program is designed in such a way so that the gains in thinking also translate into gains in basic skills and social confidence. The program is now in twenty-one schools around the country and has won two national awards as one of the outstanding technology demonstration projects in the country. Results from the first site are very encouraging and data from the replication sites are now being compiled.

I mention the above not to brag, or because I intend to use this paper as a forum to promote this program, but merely to indicate that the source of my recommendations are based on experience in developing and implementing techniques for using computers to enhance student learning. I also mention my own research because many will criticize this report for recommending that the initial focus on the use of technology be for the development of basic skills rather than the development of thinking skills. It is not that I am unsympathetic to using technology to expand thinking ability because most of my own work is in that area. At the same time I know from experience how difficult it is to in fact enhance thinking ability. As a result, this report recommends implementing now what we know how to do effectively with technology while continuing to work on discovering better ways of using it to develop more sophisticated types of skills.

The recommendations in this report will contradict some of the testimony that has been presented in the hearings that have been conducted by the National Governors' Association, as well as some widely advocated ideas about how technology should be used. The recommendations are not, however, a result of philosophic predisposition. Rather, they result from reviews of the research literature, as well as my own experience in trying a variety of approaches to using technology in schools and watching the impact on students and teachers. While there is much advocacy about how technology should be used, little of it has to do with demonstrated success in enhancing the learning of students.

DEFINITION OF TERMS

Automated capability -- A technology that reduces teacher time for performing a comprehensive function, e.g., a full-course of materials, or a K-12 curriculum, as opposed to a single skill.

Automated drill and practice -- A system that presents a full curriculum of content, along with a management system on a hard disc that tracks students are involved to work extensively on the computer (at least three to four days a week on an ongoing basis) to develop skills in a particular area.

Dry lab -- A science lab in which all the experiments are conducted on the computer as simulations.

Intensive use/targeted programs -- Programs of computer use where a limited number of students are involved to work extensively on the computer (at least three to four days a week on an ongoing basis) to develop skills in a particular area.

Meta-analysis -- A research technique that aggregates the statistical results from all studies that have been conducted on a specific issue into a single statistical result on the overall effects of the treatment.

Multiple load -- Where a single copy of a program is fed sequentially into series of computers.

Specific content drill and practice -- Programs that provide practice in only a single or relatively few concepts.

Systematic variation experiments -- Where several schools or districts use similar types of computer capabilities, but vary the way they are used at different sites in order to determine the best way to use the technology.

Telecommunicated instruction/distance learning -- Having a teacher at a remote site providing instruction to students under conditions where students and teachers can interact in real time as the lesson is going on. The two main models are two-way (audio and video, where students and teacher can both hear and see each other), and one-way (one video and two audio, where the students can see what the teacher is doing and both can talk to each other).

Videodisc -- A device that can store and present content in a mixture of text, sound, still pictures, and motion pictures. A computer-controlled videodisc system is one where the computer controls and adjusts the sequence of presenting concepts in accordance with student ability and progress.

SUMMARY

- The role of technology is viewed as increasing the learning of students in traditional ways, i.e., improving basic skills, writing, math, thinking ability, et cetera. While the major policy focus to date has been on promoting equity of access in learning how to use technology, the most critical issue in preparing students for the information economy is to develop the cognitive skills of all students to their full ability. Technology should be used to help achieve that goal.

- Technology has to be viewed in terms of the reality of a school's needs and problems. It should be used to help improve traditional learning in ways that are demonstrably cost-effective.

- There are only a few areas of technology use that have been demonstrated to be cost-effective. These are generally in the development of basic skills. The most cost-effective instructional applications at present are: automated computerized drill and practice, particularly for math computation in grades three to eight, and telecommunicated instruction/distance learning. In order to be successful, other applications of technology require very sophisticated forms of teaching and extensive computer use for each student.

- Problems with using technology are generally thought to result from inadequate training or conservatism that resists change. A much greater problem is that technology advocates generally do not understand the full dimension of the teacher learning process or the nature of the problems facing education. Most training is in the use of inadequate technologies whose use has not been validated and that are subsequently found not to work. In addition, most of the technology available for education is too cumbersome and not powerful enough to overcome structural problems in the school system.

- Much of the advocacy about how computers should be used are not likely to enhance learning and may even detract from it. The biggest problem is the advocacy to spread the use of technology to the greatest extent possible to cover the greatest number of students using the greatest number of applications. Research suggests, however, that enhancing learning requires intensive focusing of available computer time to provide extensive computer use for a limited number of students in a particular area. Widespread exposure dilutes the use of the technology so that it cannot impact learning. In addition, technology training ignores the fact that teaching ability and the quality of the curricular materials are more important determinants of the impact of technology than whether teachers know how to use it. New, more targeted approaches of planning the use of technology are needed.

- Mass training is unlikely to improve the effectiveness of technology use because little is known about the conditions under which non-drill and practice applications enhance learning, but what little is known suggests that different approaches than those widely advocated will be needed. As a result this report recommends moving away from the mass training and

implementation perspectives, and moving to: a) targeting and facilitating implementation of those few applications known to be cost-effective, b) establishing a network of coordinated pilot projects to test the effectiveness of varieties of approaches to using the newer technological capabilities, e.g., word processing, Write to Read, the Higher Order Thinking Skills Project, data bases, computer saturated classrooms, and c) developing market enhancement strategies to increase the quality and lower the cost of available technology, while also speeding up the introduction of practical new capabilities, e.g., dry science labs.

- Specific policy recommendations on how to achieve the above three objectives in such a way that they will improve school effectiveness are contained in the final section.

THE CHANGING NATURE OF WORK AND ITS IMPLICATION FOR SCHOOLING

How is Work Changing?

It is impossible to predict the future of the American economy with certainty. There are presently two very different views of the future that are summarized by Beverly Hunter (1986). Henry Levin and Russell Rumberger (1986) argue the automation is actually reducing the skill requirements of future workers due to its tendency to fragment work into small pieces that require few skills to perform. They use Department of Labor projections that suggest that the largest number of new openings in the eighties will be low-skill jobs such as janitors, sales clerks, and waiters. Other analyses, such as those by Wassily Leontief and Faye Duchin (1986), argue the opposite, that the increasing use of automation will increase professionals as a percentage of the labor force and significantly reduce the proportion of clerical workers.

While Levin and Raumberger are probably correct to the extent that we will not need large increases in the number of scientists, or that some categories of technical workers such as programmers will never increase to the extent that they will comprise a substantial portion of the workforce, it is hard to agree with their assertion that automation has simplified work. Agriculture is probably one of the most automated sectors of the economy. While technology has simplified and eliminated the simpler manual tasks, being successful in agriculture is clearly a much more complex process than it once was. Successful farmers must use careful management techniques and must be experts in finance. While technology may have made it possible for the factory to produce industrial goods with very little skill and displace the skilled artisans, industrial production is being replaced by service forms of work -- much of it highly skilled. In addition, whatever industrial production remains in this country will increasingly involve making highly sophisticated products, or those with short life spans (so that is does not pay to set up factories overseas).

The best illustration of how automation increases the sophistication of work was expressed in a recent article in The Wall Street Journal (May 22, 1986) by Peter Drucker as follows:

> Automation on the factory floor requires...that "first-line supervisors" change into genuine "managers." The traditional functions of first-line supervision are being taken away by automation and either transferred to the work force or built into the process. Indeed, there is no supervision in the traditional sense in the automated plant. But instead there is a need on the factory floor for planning ... for teaching and for coordinating the various technical services such as plant engineering and production scheduling -- all of which has been traditionally done either by higher management of specialists. First-line supervisors thus have to be redirected; they have to acquire new vision, new values and new skills.

There clearly will be large numbers of low-paid, low-skill jobs in the service sector. At the same time, increasingly sophisticated forms of automation, such as intelligent robots, will more likely replace routine, not skilled, work. High paying work of all types will require increasingly sophisticated skills -- in all areas of work. Particularly valuable will be individuals capable of developing new ideas, exerting initiative, combining knowledge from a variety of fields to develop and apply new techniques, and functioning in more open-ended environments. This can be seen in General Motors' reorganization of work to produce the Saturn, the increasing sophistication of tool and die workers to design and produce parts of autos and computers to ever small tolerances, the increasing importance of electronics knowledge in auto repair, et cetera. At the same time that technology is displacing routine work, the technology itself will become increasingly easier to use -- making it more widely available for use in increasing number of application -- **without requiring extensive training in its use.**

The availability of technology to automate routine work will free individuals to do more sophisticated types of work, and international competition will require us to compete on the basis of new and more creative products and services. This will make high paying jobs increasingly dependent upon the quality of the value added by the intellect or the entrepreneurism of the individual involved. The question becomes "Who is going to have access to such jobs, and what role are schools going to play in determining who does have access?"

Implications for Education

If the above analysis of the changing nature of work is correct, the implications for schooling are as follows:

- High quality education in a traditional sense is going to become more critical and a greater determinant of success in the marketplace.

- Teaching students how to use technology per se will have little long-term payoff. **The ability to operate technology is of little value if the technology is simple to operate.** Industry is investing hundreds of millions of dollars to make technology people literate. The payoff for both students and society is in developing the ability to engage in sophisticated forms of problems solving as well as being expert in a number of fields. Such individuals will be able to apply technology to solve difficult problems.

- **Equity in preparing students for the eighties and nineties requires developing the intellectual skills of all students to their fullest abilities.** While it is not clear if we will need to produce more scientists,[1] it is clear that we will have to increase the analytical skills and science knowledge of the average student (NSF-DOE 1980).

HOW SHOULD WE MEASURE PRODUCTIVITY FROM USING TECHNOLOGY?

Perspectives on the Role of Technology in Education

There are at least three views on this issue. The first is that students should know how to use technology and be aware of its implication for the future. This perspective focuses on providing information about technology. This approach, generally referred to as **computer literacy**, treats the technology as an object of instruction. A variety of curricular approaches have emerged over the past three years to develop computer literacy. The first emphasis was on the teaching of programming, the second on K-12 sequenced curricula covering varieties of issues related to technology, and the third on learning to use a variety of capabilities -- technology as a tool.

The second perspective on technology is that it should be used to increase the efficiency and effectiveness of the instructional process. This view argues that the primary role of technology in any setting is to enhance the effectiveness with which the organization carries out its mission. In the case of education, the primary mission is to provide a higher quality education. Such application of technology is increasingly critical given the widely publicized problems facing education such as teacher quality. This will hereafter be referred to as the **effectiveness enhancement** perspective.

The third perspective is that technology should be used to increase certain types of learning outcomes. This group usually argues that computers should not be used for drill and practice applications but that it should be applied only to improve thinking skills. This perspective, which will hereafter be referred to as the **limited effectiveness/access equity** one, often derives from a concern that drill and practice applications will be relegated to poor students while rich students will be provided the opportunity to use computers to develop thinking and programming skills. This has led to the policy concern of equity of access to computer technology, a goal that is easy to achieve if computers are not used for drill and practice.

More school districts base their computer use plans on the "computer literacy" perspective. Listed below are examples of typical types computer literacy objectives from school district plans, and their "effectiveness enhancement" equivalents.

COMPUTER LITERACY	EFFECTIVENESS ENHANCEMENT
Students will learn how to use the computer as a tool for writing.	Students will write on the computer in order to improve the quality of their writing.
Students will learn the history of the computer industry.	Students will use social studies computer simulations to better understand forces driving American history.
Students will learn how to use a Computer-Aided Design Program.	Students will use a Computer-Aided Design program to increase the quality of their design.
Students will learn how to conduct science simulations on the computer.	Through the use of computerized science simulations, students will increase their ability to generate and test hypotheses.
Students in grades two to six will be in the computer lab one day a week. All teachers will have a computer in their classroom.	There is no equivalent as the comparison objective has nothing to do with learning.

The "Access Equity" and computer literacy perspectives are usually the ones that state policies are based on. This is reflected in the tendency to pass mandates for computer literacy and to spread technology funding as widely as possible and provide as many computer use experiences for as many students as possible.

Recommended Perspective for Defining Policy and Cost-Effectiveness

The recommendation of this report, however, is that both district and state policy should be based primarily on the "effectiveness enhancement" perspective. Policy should focus on facilitating the use of technology to enhance traditional forms of learning in measurable ways. As already suggested there is little long-term payoff in training students to be computer/technology literate. That does not mean it is not desirable for schools to include word processing in their office skills curriculum. It only means that such technology specific skill programs will be valuable only for a short period of time -- much as keypunching appeared and disappeared in the seventies. As soon as the cost of voice recognition computers decline and we can talk to computers, word processing and keyboarding skills will be as valuable as keypunching skills are now. (The only long-term skill will be for the office workers to have the types of analytical and information processing skills that will enable them to perform the type of work currently done by systems analysts.)[2]

There are also problems with the "limited effectiveness" perspective. While it is important to figure out ways to use computers to enhance thinking skills, it makes little sense to eliminate from consideration use of computers whose effectiveness has been documented. Saying that computers or technology should not be used to enhance basic skills is akin to saying that robot technology should be used only to make spaceships and not automobiles.

The concern over equity of access to computer use has to be tempered in light of research that integrating programming into coursework may inhibit the learning of students performing below average (Clark 1985). It makes little sense to rule out the use of a technology such as drill and practice that has demonstrated an ability to reduce learning gaps in favor of a use that will expand it. The problem is not that poor kids use computers for drill and practice, but that there is little provision in the schools for going beyond such teaching in the curriculum via any technique. The only inequity would be if there was not an attempt anywhere in the schooling process to challenge the poorer students intellectually. It would further be inequitable if the computer drill and practice was not carried out with sufficient allocations of time to produce measurable improvement in basic skill scores (see the section on research findings for guidelines as to the amount of time required). It would also be inequitable if once drill and practice had raised their scores, poor students did not then have access to courses in programming and more sophisticated uses of computers. None of this, however, is a valid argument against taking advantage of the documented effectiveness of computers in increasing basic skill scores of low-achieving students.

The recommended perspective of this paper is that technology should be used on a large scale only under the conditions that it enhances cognitive/academic development in measurable ways (preferably on traditional measures) at the same, or at a lower cost, than other available approaches.[3] Computers should not be used simply because of reports that they stimulate student interest or increase motivation. While these are indeed important occurrences, they are not by themselves sufficient if not translated into learning improvements. Computer advocates consistently underestimate the difficulty in making such transfers.

There could, however, be justification for waiving such a stringent condition for cost-effectiveness in the case of using technology to assist the severely disabled. For such individuals new technologies, such as robotic arms controlled by voice or eye movement, or text to sound converters, may provide the only option for functioning.

WHAT DOES THE RESEARCH SAY ABOUT THE COST-EFFECTIVENESS OF TECHNOLOGY?[4]

Effectiveness of Computer Technology

Most of the available research focuses on drill and practice uses of the computers, although some research has begun to appear on the newer micocomputer-supported capabilities such as word processing, Logo (a widely used programming language for children that is widely advocated for developing thinking skills), and varieties of simulations. In addition, interpretation of the research is complicated by a number of serious methodological

problems. Many of the studies that find the most significant results are either of short duration (so novelty effects may be causing the gains) or fail to control for the quality of teaching or other instructional process variables. As such, the results of a single study, or a single synthesis of research, can lead to highly misleading findings.[5] The conclusions presented in this paper derive from comparing some of the conflicting results of research syntheses with systematic variation experiments in Los Angeles and Arkansas and this author's Higher Order Thinking Skills project, as well as extrapolating research generated in school effectiveness research to equivalent circumstances in technology environments. A dash of common sense was also thrown in.

Existing research generally concludes that computers can substantially enhance learning. Richard Niemiec and Herbert Walberg (1986) concluded in their meta-analysis that the overall effect from computer use was to raise scores substantially (.42 SD units). The issue of whether such effects are cost-effective relative to nontechology approaches are not clear. Most research on technology compares the use of a technological intervention to no improvement effort. What would happen, for example, if a teacher was trained to be a more effective teacher and then taught two different groups of students, one using computers and the other without. There are very few studies where teacher effects are controlled, but when Richard Clark (1983) separated our such studies from the others, the relative effect advantage of technology was reduced from .5 to .13 SD.

In the absence of studies directly comparing computer interventions with other methods for improving learning, researchers have attempted to compare the cost-effectiveness of computer intervention studies, with separate studies of other types of interventions. There have been two such studies that have compared computers against the improvement interventions of peer tutoring, reducing class size, and increasing time on task. Henry Levin, Gene Glass, and Gail Meister (1984) concluded that the use of computers was the least cost-effective and peer tutoring the most effective, while Richard Niemiec et al. (1986) concluded that computer use was the most cost-effective intervention of the four. (Of these two studies it is this author's opinion that the Niemiec study is more statistically valid but the reader can make up his or her own mind by reading the two competing views in the June 1986 issue of the Phi Delta Kappan.[6]) Regardless of which cost-effective analysis one wants to believe, however, the overall cost-effectiveness of computers is less important than the question of the cost-effectiveness of particular uses of computers. It is also clear that when computers are effective, they are very effective.

While it is clear that computers can produce very significant gains under some circumstances, these benefits are clearly not universal. Whether computers enhance learning is a function of the following factors: type of application, grade level, amount of use, ability level of the student, quality of teaching, and in many circumstances, the quality of the school's educational program. The following is a summary of findings organized by the type of application (Pogrow 1986):

1. Comprehensive Drill and Practice:

Math drill and practice is more effective than reading drill and practice.

The systematic variation studies in Los Angeles found that the optimal time for math drill and practice appears to be twenty minutes a day four to five days per week for at least a year, and probably longer for below-average students, while ten minutes a day seems optimal for reading drill and practice.[7] Math drill and practice appears to be most effective in grades three to eight for computation and earlier grade levels for concepts (although this author is unaware of any systematic variation studies at the high school level). While long-term use continues to enhance the learning of computation, there may be diminishing returns for below-average students after a year because of the increasing reading ability needed to understand advanced math concepts.

Automated drill and practice software that is consistent with the presentation of items on the standardized test used to test students is more effective than nonautomated software that is not aligned with the test.

The effectiveness of reading drill and practice is probably partly determined by the quality of the overall language development program in a school. The benefits may be greatest at the earlier grade levels.

Computer-Managed Instruction (where the computer merely tracks objectives accomplished) has little effect on cognitive development until the high school years.

Commercially supplied software is generally more effective than materials developed inhouse.

2. Teaching of Specific Types of Concepts

The reading level of a software is an important determinant of its effectiveness for below-average students, and the quality of reading instruction in a school is possibly an important factor in the potential for effective uses of computers at the upper elementary and secondary grade levels.

Computer literacy has no effect on cognitive development, and the occasional circulation of students into a lab once a week or other forms of random use has no impact on learning. Providing occasional computer use activities, be it scheduling students in a computer lab once a week or rotating students to a computer in a classroom, will have no impact on learning.

It is not known if occasional specific content drill and practice will enhance learning.

Computer-aided instruction reduces learning time, but short-term computer use may not enhance retention -- even if it produces an immediate gain on a test.

3. Simulations and open-ended tools (programming, word processing, data bases, and spreadsheets):

Training in a programming language does not transfer to provide benefits in traditional subjects, and in most classrooms, learning one set of programming procedures does not seem to transfer to another.[8]

Integrating programming and simulations into high school courses helps high ability students and inhibits low ability students (Clark 1983). (This is probably a result of reading requirements to use the software and lack of student experience in thinking ideas through.)

Research has not yet been able to demonstrate that the use of word processing enhances the quality of writing, or that programming or spreadsheets enhance math skills.[9]

Research from the Higher Order Thinking Skills projects, while not yet conclusive, suggests that simulations and word processing can indeed enhance the learning of below-average students in grades four to six. The following conditions must, however, be present: there must be extensive computer use over a long period of time; there must be master teaching; and there must be a sophisticated curriculum that either describes how to use a given program as an opportunity to synthesize information or how to link concepts from one computer environment to another.

Research from the Thinking Skills Project also suggests that occasional use of thinking development computer activities will have no impact on learning for low achieving students at the elementary level. It took approximately two to three months of daily computer activity (thirty-five minutes per day) before low-achieving students were willing to try out ideas on their own, and it took six months before they recognized that an initial strategy was not working and consciously switched to a new one. It was almost a year before most would express complex ideas before the entire class.

Good software and teachers trained in their ability to use it are very minor components in determining whether such systems will enhance learning as compared to the three other key factors listed above. Good software must exist and teachers need to know how to use it, but these factors by themselves are not sufficient to produce learning in average to below-average students.

The most important determinant of the effectiveness of computer use is the sophistication of the teacher dialogue with the students. (Dick Howell of Ohio State University, who is a leading researcher

in the use of computers with special education students, indicated in a conversation that he and at least one other researcher have reached the same conclusion with respect to using computers with learning disabled students.) Sophisticated forms of curriculum that use computer environments to synthesize ideas and link ideas from one computer environment to another also must be developed.

Effectiveness of Educational TV and Other Visual Media

High quality home TV can enhance learning to some extent by itself, although the major effects result where both pre-instruction and high quality follow-up discussion occurs -- both provided by adults.

The most effective use of video is to teach basic skills and facts as opposed to skill development.

Students bring their own perceptions to the watching of video material. As a result, different students will learn different things from watching video materials. If curricular content is to be learned, the teacher must do pre- and post-teaching activities. Little is known about the effects of coordinating home watching with classroom discussion. This is largely due to the difficulty in coordinating the sequencing of classroom content with network TV schedules.

Meta-analyses of video-based instruction cited by Johnson (1986) find much smaller improvement effects than the meta-analyses on computer-based instruction.

Telecommunicated instruction/district learning, where there is real time two-way instruction between a teacher and students in a remote site, is as effective as a teacher in front of the classroom.

Implications of the Research

There are two common elements to the research on computers and video technology. The first is that the only real validated research has to do with the effectiveness in developing basic skills -- primarily at the elementary grade level. Techniques of using technology to enhance the thinking of the average student in schools have yet to be demonstrated. The second element is the importance of highly skilled teaching to virtually all use of the technology. The notion that technology could be substituted for teachers, or even reduce the sophistication and extent of the teacher involvement required in the teaching process, are not likely to be possible in the near future.[10] Indeed, it is possible that as schools look to technology to improve the thinking skills of students, even more sophisticated forms of teaching will be required. As such, technology has to be viewed essentially as an add-on rather than a substitution cost in most cases.[11]

There are some exceptions to the above generalizations. Telecommunicated instruction/distance learning and certain key administrative application are uses of technology that can substantially reduce costs to provide a given level of service and thus would not be an add-on. The major exceptions to the

generalization of needing high quality teaching to make technology effective is math drill and practice, which seems to produce substantial gains very consistently regardless of the circumstances (as long as adequate amounts of time are provided and the software is of high quality), and highly motivated, high ability students who can probably learn by interacting with technology on their own.

At the same time it is clear that some of the newer forms of technology that have not yet been demonstrated to be effective have potential. In addition, as the quality of the technology improves with respect to hardware, software, and delivery systems, it is likely that the overall effectiveness of technology will increase in many areas. **What is distressing, however, is that much of the advocacy for the use of the technologies act as though the benefits have been proven or are a foregone conclusion. Even worse, much of the advocacy is to use the newer technology in a way such that it cannot possibly be effective.**

While research cannot prove that some of the newer capabilities can enhance learning, the research referred to above provides some guidance as to the conditions that must be in place if it is possible for a given use to be effective: specifically, if the newer types of currently available technology are to be effective, teacher quality must be improved, extensive time on the computer must be provided for each student, and related curricula in the classroom must be upgraded.

Suppose, for example, one wanted to use word processing to increase vocabulary and improve writing. Teachers would need to have their skills in teaching reading and writing substantially upgraded and students would have to spend substantial amounts of time on the computer for it to be effective. Common sense also suggests that the overall language arts curriculum would have to be upgraded and teachers would have to assign a lot more writing. (In order to enable teachers to assign more writing without increasing their workload, it would be ideal to have a word processor equipped with a grammar checker and pre-writing coach, as well as a speller checker.) While most schools and districts in the United States now expose students to word processing, virtually none have programs that would meet even most of the above criteria, hence most schools fail to find that the use of word processing enhances writing and vocabulary -- even though it has tremendous potential.

The reason that schools do not use word processing, or any other capability, in accordance with the above guidelines is that computer advocates prefer to see widespread use rather than targeted focused use. Schools with limited resources can either provide a little computer use to everyone or intensive use to some.[12] Political factors, plus the naive belief that the technology is so powerful that it will automatically produce learning, or that using the machine is such a powerful and thrilling experience that it will change people's lives and opportunities, has led to the emergence of the equalized widespread use model. The widespread use, let's-get-everyone-aboard model has been applied to every conception of computer use that has become popular in the eighties. Students are rotated in and out of computer labs periodically. The amount of use that everyone gets is determined by the

number of computers available rather than by the greatest need or opportunity, or by the amount of time and teacher quality needed to produce gains. As a result, it is not only unlikely that schools will be able to use the newer technologies effectively, it is also probable that even the validated applications that already exist, such as math drill and practice, will be used effectively.

Establishing programs that focus the use of computers on targeted populations for a few educational needs require different allocation and planning techniques than those advocated by computer user groups and computer journals (Pogrow 1985).

It is time to carefully look at the limitations suggested by the research, examine the strengths and weaknesses of the place called school, and design more realistic and focused approaches to using technology that have a change to improve learning.

WHY SCHOOLS DO NOT USE TECHNOLOGY EXTENSIVELY OR EFFECTIVELY

Schools are constantly accused of rejecting the use of technology out of innate conservatism or fear. Are schools technologically backwards? At one level, schools, like business, are investing in microcomputer technology at a record rate. According to the April 14, 1986, issue of Infoworld, the number of micros in schools has increased from 292,000 in 1982 to a projected 1.4 million in 1986. At the same time there appears to be little systematic use of that technology in ways likely to provide educational benefits. Whatever improvements schools have made in basic skill scores seem to result primarily from nontechnology school effectiveness strategies. Nor has technology accomplished what it was advertised to be able to do, and may have accomplished the opposite. According to a recent survey, the number of college freshmen expressing career interest in the computer field declined 50 percent between 1983 and 1985 despite the major expansion of computer literacy programs in the high schools during that period (American Council on Education 1986). Steven Pulos and Sarah Fisher (1986) found greater interest in computers among students who had not had instruction in computers than among those who had.

The solution usually proposed to the problem of the apparent failure of most computer use activities to impact outcome measures is to "provide more training." Unfortunately, the problem is not that simple, and much of the training is actually making the problem worse. The real problems lie in the power of the technology and the nature and extent of the problems in schools.

Practical Limitations of Current Technology

In any organization where technology is being considered to help improve the effectiveness and efficiency there has to be clear and substantial benefits before its incorporation can be considered. To the extent that the use of the technology requires substantial reorganization of the work process, the benefits have to be more substantial yet. To be effective technology must reduce work, automate most, not just a small part, of an operation, be affordable, be easy to use and implement, and provide a wide range of tangible

benefits. In addition, the technology has to work within the real needs and problems of the organization.

Schools presently have to be viewed as organizations with major problems, particularly in the area of teacher quality. There is also very little discretionary spending power. Schools recently have been doing a better job in improving basic skill performance, but national assessment data consistently show poor student performance on tasks of comprehension, problem solving, and written expression. "A Study of High Schools," sponsored by the National Association of Secondary School Principals and the National Association of Independent Schools, found that most students are not being challenged to use their intellectual capabilities (for example, Sizer 1984).

Within such realities it makes no sense to put a tool that requires even more sophisticated teaching skills than using noncomputer techniques to perform the same task, such as Logo, into an organization with teacher quality problems and then compound the problem by trying to get all teachers to use it. All that can accomplish a lot of bad teaching around Logo, word processing, spreadsheets, and so on. The notion that exposing teachers to technology will make them better teachers is simply not true. Teachers teach as well, or as poorly, with the computer as they do with books.

Another problem is that effective technologies provide the most help in the areas where schools least need it. As discussed in the previous section, the only documented benefits from technology are in the basic skill area, with gains in more sophisticated uses primarily impacting high ability students. Technology has not yet been demonstrated to provide added advantage where the needs really are, i.e., thinking skills for the average to below-average student. There are many nontechnology techniques that are proving effective in increasing basic skills that do not require more sophisticated levels of teaching, while the high ability student is getting a good education without technology. Generally, it is not prudent for administrators to put their major eggs in the technology basket in order to improve student learning. Using technology the way they are "supposed to" will usually prove to be extremely disruptive to the existing curriculum and school organization. It often takes enormous effort to persuade all the staff to use technology, and to add new content to an already overcrowded curriculum. The benefits are rarely worth the effort.

Consider for example the response of a social studies teacher to technology:

> There are 180 instructional days; a period is fifty minutes long. We are required to have five to seven days of testing. In the time that's left I'm expected to cover the entire U.S. experience from discovery to Vietnam. In addition I'm expected to spend nine weeks on the Criminal Justice System (Johnston et al. 1984, p. 29).

Is there really that great an advantage under such circumstances of integrating an occasional computer-use activity into the course, or adding a unit on the history of the computer? Adding computer activities takes additional time, which means less time to accomplish existing important

objectives. One can of course argue that the objectives the teacher is required to cover are no longer important, but few would agree. The moment that a technology requires you to give up one important objective to try and obtain another, its value diminishes.

A second problem is that much of the current computer technology is nonautomated and actually increases the amount of work for teachers who use it. The extra work takes the form of loading diskettes, writing lesson plans for using the computer, scheduling students to use the computer, et cetera. Consider, for example, one of the more popular, but expensive, drill and practice math system that uses eight discs to span grades one to eight. The first four discs in the series allow for multiple loading (using one disc to load the program into several computers). The management system, however, cannot be used except on a single machine. The remaining expensive discs can be used only for one machine, which means a set must be bought for each computer. In all cases, however, the management system can be used only for a single machine. This means that even if the district spends the money to buy sufficient copies, when a teacher sends a group of students to the computer lab, every student's progress report will be on a different printout, mixed in with students from every other class.

Most other software is even worse because they do not span a series of skills and one therefore needs to buy sets of discs and organize and sequence them -- and then figure out how to use them. The Higher Order Thinking Skills project uses approximately forty different programs over a two-year period whose use must be organized, sequenced, and manually loaded one machine at a time. Few programs are available that can work automatically on a hard disc with a management system. Effective technology is supposed to reduce work.

There are two primary reasons for the critical software problems. The first is the small size and fragmentation of the education market. The cost of computers and word processors has come down because they are used by the business market. Educational software has a more limited market, one that consists of large numbers of units that have to be persuaded independently to buy the product, and then they buy only small quantities. When the expected mass home market for educational software did not develop (blame the videotape machine for that), the remaining school market was not large enough to support the type of research and development expenses required to produce state-of-the-art software.

The second problem has been a lack of vision on the part of software developers. Educational software has evolved with few standards so that every system is different in format, procedures, and storage conventions. Unlike the commercial software sector where the emphasis is on standardization, networking on hard discs, and (increasingly) removing copy protection, educational software is a confusing, inconvenient product. The product is more geared for an individual home than for a school. Though the technology to do so is readily available, few companies have released automated hard disc versions of their software. In some cases vendors who developed automated versions decided not to release them.[13] Faced with a small educational software market made even smaller by piracy, many companies are trying to develop strategies to persuade or make schools buy a copy of the software for

each computer. This is done by promoting that multiple loading is illegal and by making it difficult to do multiple loading or to use the software in an automated fashion.

Unfortunately, this is an unrealistic strategy. Inconvenient software will not be used and schools cannot and will not ever likely purchase a piece of software for each machine -- any more than business is willing to do so. This is an approach where everyone loses. The real key is to develop new approaches to marketing and pricing. At the same time, more realistic conceptions are needed about how technology is to be used.

Finally, occasional use of nonautomated technology requires extensive sequencing activities that take a lot of extra time and energy -- with little payoff. In addition, even if the occasional activities are linked to the curriculum in the name of providing additional means of reinforcing content, this may not provide extensive benefits (unless it is used strictly for a few key focused applications where the students are not learning through conventional means). Much of current pedagogical theory suggests that traditional structured lecturing is the most effective way of teaching content, and that multimedia approaches are often less effective.

Limitations of Technology for Developing Thinking Skills

Improving the quality of science and math education for all students, and doing a better job at developing thinking skills, requires very extensive curricular and pedagogical reforms. Technology cannot by itself offer much help -- particularly for the average and below-average student. The technology at present is incapable of providing the sophisticated forms of interaction needed to develop thinking. It can tell a student only whether an answer is right or wrong -- not why the answer is wrong and then help remediate that specific problem. The technology cannot even allow a student to respond in his or her own words. While such capabilities will be feasible in the future with artificial intelligence the technology cannot presently easily help.

Operating the Higher Order Thinking Skills project requires writing two years of daily lesson plans, each of which takes eight hours to write. It took two years to work out the procedures for writing the curriculum and to develop an approach to teacher training that would improve the ability of teachers to maintain a process-oriented environment. Using the newer technological capabilities is definitely not easy.

Limitations of Training Programs

The first problem with training as previously discussed is that it assumes that most applications of technology can enhance learning. Clearly that is not true -- so training becomes an exercise in learning new things without any real purpose. After a recent presentation by this author on the pessimistic research findings from the use of Logo, a teacher came up in tears and shared that she had devoted her summer to getting the best available training in the use of technology and had taken what the university had recommended -- which was twelve units on how to use Logo.

The second problem is that training often encourages participants to use a wide variety of applications rather than developing the ability to use the few high potential applications under conditions where they are likely to be effective. Third, in the absence of a validated approach as to how to effectively use a technology, each new capability is assumed to work the same way the previous one did not -- essentially, run the kids through the lab and hope that this time around something good will happen. It is impossible to train someone to do something that is not yet known how to do. In many cases the advocates point to a teacher who appears to have used the technology successfully and then attempt to replicate what that teacher has done. There is, however, a major difference between what one gifted teacher can accomplish and what can be transferred to the field as a whole. A year after the wave of that training has swept the country, there inevitably are articles by proponents blaming the classroom teachers for not making it work, or pointing out that using the technology was more complex than they had anticipated.[14]

The fourth problem is that most trainers assume that if teachers know how to use a technology, they can use it effectively. As already suggested, being able to use the technology is a very small component of being able to use it to enhance learning. The most importance factor is that the teacher must become a different and better teacher, which is very difficult to do on a large scale -- and which few training programs know how, or even attempt, to do. The irony is that those who are claiming that there is a monumental need to train people to use technology are themselves often divorced from fundamental research findings in pedagogy and curriculum development.

It is hard to keep arguing that lack of training is the problem. To the contrary, there has been an enormous amount of technology training nationally with little benefit. More of the same will not change anything. Indeed, in this author's experience, states that have spent the most money for training and training centers often have the poorest computer use programs in their schools.

Summary

Despite widespread advocacy for using technology, most of it can help overcome the enormous problems facing education. Training programs only push the use of impractical nonvalidated ideas, simply because they exist. Vendors often criticize educators for not adopting their technologies that they claim have been validated. Usually, however, they have not been validated under accepted norms of research procedure. The instructional technology of today is somewhat similar to administrative systems of the early seventies -- expensive, difficult, and inconvenient to use, and the few benefits provided were often swamped by the problems in working with it. (It is only in the past half year that administrative software has become highly automated.)

Rather than being a problem, educators' reluctance to embrace the use of nonautomated technology is probably smart. A bigger problem is the educator who adopts technology in lieu of, or as an excuse not to engage in, fundamental curricular reform. The trick is to first solve fundamental educational dilemmas, while making provisions for practical incorporation of those technologies with proven track records in ways that will work. It is

also important to redirect energies away from training everyone to use existing technologies and begin to implement policies to help improve the quality of the technology. **The best training program is having easier to use, higher quality, more powerful, and more automated technologies than are presently available.**

RESTRUCTURING EDUCATION

If education is to become more effective, techniques for improving teacher quality and leveraging the role of outstanding teachers must be used. In addition, schools must figure out ways to update the curriculum. This includes offering courses in languages of the major economic allies and competitors, strengthening requirements, and incorporating some of the recommendations of "A Study of High Schools," sponsored by the National Association of Secondary School Principals and the National Association of Independent Schools, to include more multidisciplinary project activities. In addition, those applications that are demonstrably cost-effective should be incorporated into the effort to improve schools.

Cost-Effective Technologies

There are relatively few applications of technology that can presently be viewed as cost-effective. At the same time, the use of the applications can provide tremendous benefits.

Among the available technologies, **the only ones that can be viewed as cost-effective, both in terms of research findings and practical organizational issues, are automated drill and practice in math at the elementary and middle school years, and telecommunicated instruction/distance learning.** (Reading drill and practice may be cost-effective, but probably only in the early elementary years, and only if there is a coordinated effort to improve the school's overall language arts program.) In telecommunicated instruction/distance learning, a single teacher provides instruction to a series of sites where students can interrupt and ask questions. Telecommunicated instruction/distance learning is generally used to provide elective courses to schools who cannot afford or cannot find qualified teachers. Another potential use would be to provide bilingual learning opportunities to students across a region where there are small pockets of students with home languages that are relatively uncommon. (While this latter application has not been researched as of yet, the research on video presentation in general would predict that it would be effective.)

Contrary to the perspective that school administrators are afraid to use technology, telecommunicated instruction/distance learning is expanding very rapidly. According to the April/May 1986 issue of School Tech News, it is expected that half of school districts in New York state will be involved in telecommunicated instruction/distance learning by next year. (According to the May 7, 1986, issue of Education Computer News, a seven-district consortium in Minnesota is improving on the more prevalent practices of using either phone lines, microwave, or cable systems for telecommunicated instruction and is the first to establish a state-of-the-art fiber optic video network.)

There are several other cost-effective applications that are supported more by practical concern than by documented research. The first is computerized career and college guidance systems. Such systems provide a data base of up-to-date information on career opportunities and college offerings that students can extract on their own.

Another rapidly growing cost-effective use of computers is for school and district management. Student management generally includes attendance, scheduling, grade reporting, test scoring, and student objectives proficiency. Financial management includes accounting, payroll, personnel, and inventory. Information is the most rapidly growing resource in education fueled by increasing reporting requirements at all levels of governments as well as increasing demands for accountability. Five to ten years ago such management activities could be performed only on large mainframe computers affordable only by the largest or richest districts. Smaller districts generally had to rely on computer service from regional service bureaus or county offices of education. As microcomputers and minicomputers have become increasingly powerful and inexpensive, these capabilities have come within reach of most schools and districts. Indeed, the market for school administration software is growing rapidly. There are now at least twenty-five companies producing full capability student management programs. The number keeps growing and several large corporations have acquired school management software companies.

Also significant is the fact that the software more recently developed for minis and micros is usually superior to that available ten years ago on large computers. In addition, it is usually far more cost-effective at present for schools to get their own systems than to continue to rely on county offices or services bureaus, despite the high cost of the software, which generally ranges from $4,000 to $10,000 per school, and up to $50,000 for a large district. The savings in terms of extra clerical help and greater efficiency usually easily justifies the cost.

Implementing Cost-Effective Applications

To take advantage of applications proven to be cost-effective, the following should occur:

- All districts should provide twenty minutes a day of automated drill and practice in math, four days a week, for all students more than one and a half years behind in math before the eighth or ninth grade until they reach close to grade level.

- All schools should have plans to provide a series of telecommunicated instruction courses at the high school level, particularly in the areas of math, science, and language. The languages offered should include at least one of either Chinese, Japanese, or Russian. Telecommunicated instruction also should be used to deliver bilingual/ESL instruction at the elementary level for districts with small pockets of many different ethnic groups.

- All secondary schools of reasonable size should have a computerized student management system of their own or multiterminal on-line access to a central system that allows school personnel to retrieve needed information on their own without technical intervention. All elementary schools should have a demographic data base system integrated with a word processing system to generate lists, counts, and reports. Most districts should have a centralized financial management system with on-line inquiry to the schools.

Potential Cost-Effective Applications in the Near Future

Over the next year or two it can be anticipated that automated word processing will be available for the more powerful microcomputers. Such word processors will have grammar checkers, as well as speller checkers and pre-writing tutors. Such systems will make it easier to use word processors to improve writing and vocabulary, and to incorporate more writing and project assignments in secondary level courses. At the same time, they will require more expensive and sophisticated computers than schools typically have.

It should be possible within two years to three years to have automated dry science labs on computer controlled videodiscs. Such a capability would provide an entire course worth on science experiments that could be performed on the computer instead of using costly lab facilities.

In the administrative area, it will become increasingly feasible to establish electronic mail systems in several years.

Within a year or two, the computer may become a cost-effective device to individualize physical education programs. The computer can assimilate basic health data about an individual and prescribe health improvement goals, along with a diet and exercise program to meet them.

An impressive array of products is starting to become available that enables severely disabled individuals to function. These include text to sound transcribers, robot arms, and graphic representation of speech. As mentioned earlier, it is hard to think of such capabilities in cost-effective terms, because there often is no other option to consider. At the same time, appropriate market development policies could help significantly reduce costs over the next two to four years of many of these capabilities, and would also ensure that some of these capabilities which have been developed to help adults function in the work place would also become available to help youngsters learn in school. For example, Karyl Hall, project director of the Evaluation and Learning Facility in the Palo Alto Veteran's Administration Hospital, has developed a voice-activated robotic arm for adult quadriplegics that now costs $35,000. She indicated that such technology could easily be adapted for use in schools, and the cost reduced, if there was research and development support, and a market.

Within five to eight years, it may be possible to have artificial intelligence software that will be capable of not only presenting information, but also for determining the cause of student errors and interacting with students to help them realize their mistakes (as opposed to existing systems

that simply indicate that a response is wrong). Artificial intelligence probably will make it possible for technology to take over teaching concepts, and probably will make it possible even for below-average students to use technology to learn advanced concepts with substantially reduced adult intervention.

Piloting Emerging Technologies

There is a need to learn whether the newer emerging forms of technology can be made to be effective and under what conditions. The advantages of pilots are that it becomes possible to test ideal forms of use that are currently too expensive to implement on a widespread basis, while generating valuable information on how to use it by the point in time when it becomes more affordable on a widespread basis; costly large-scale mistakes are avoided by testing the use of the technology; and the knowledge gained from the test can be used to design effective training programs. [15]

Piloting is essential because, as already suggested, it takes several years to figure out how to use a technology effectively and the time allocated per student must be extensive -- hence expensive. Most districts implement newer capabilities on such a wide-scale basis that they use versions of the technology that are affordable rather than ideal. For example, a high school office applications course may be taught on a type of low-cost microcomputer that is never found in a business setting. As a result, the technology that is used is less powerful and automated than what is available and needed, and as a result the program ends up being less effective than it should be.

The only way to ascertain how cost-effective newer technologies are is to back away from the advocacy about how they are supposed to be used and systematically try varieties of targeted approaches to using them on a small scale and then evaluate their effectiveness in measurably affecting learning. Such experiments should be conducted for at least two years before they are pronounced a success or failure. (In one large district recently visited by this author, a pilot of an expensive program was declared a success after only six months, before any test scores were in. The basis for judging it a success was that everyone liked it.) In addition, each type of approach needs to be tested in several sites to make sure that the benefits are consistent and replicable.

Unfortunately, what is happening is that everyone is settling on how these new technologies are "supposed" to be used, and training is already proceeding. Thus, there is little systematic variation as to how they are used, and once again they are being spread around too widely to have any impact. Everyone "knows" you are supposed to link directly with curriculum content and it is supposed to be infused into all curriculum areas. The Higher Order Thinking Skills project violates most of these assumptions. For example, the program provides little direct linkage to the curriculum; it is done as a pullout with only a single specially trained teacher in a school with little or no computer use in the regular classroom. So far, the data on its effectiveness for both thinking and basic skill development, while not conclusive, is promising. At the same time, one state has not allowed districts to use state technology funds to test this program because it was

judged to violate equity considerations and use an approach that is likely to fail. While this program may ultimately fail, it is still important to test a single teacher nonintegrated approach because if it does work, that will mean that it is not necessary to have all the teachers using sophisticated forms of technology to produce sophisticated outcomes. The implications of such a finding, particularly if it also extends to the junior high school program, means that it would be possible to have a master/mentor teacher working with the technology to develop students' thinking skills as either a pullout or separate course without having to extensively restructure the curriculum of the classroom. This would be a more practical approach to sophisticated forms of computer use for all students until artificial intelligence comes along. The only way to find out if this approach works is to try it.

Another case this author recently encountered of people making something work that was not the "right thing" to do was a principal who targeted the use of computers on improving language arts in his school for a few grade levels. He combined word processing activities with drill and practice, and trained the teachers how to teach writing and reading better. Language arts scores rose dramatically (as the research section of this paper would predict). When he showed off the program he was severely criticized by the district's computer coordinator and a county tech specialist for not having an appropriate computer program because the students were not being taught programming, spreadsheets, the history of computers, data bases, et cetera.

The problem is that there is resistance to implementing or testing innovative approaches that run against the grain of popular advocacy about how things are supposed to be done. There is a need, however, to test many other types of strategies before the field settles in on how these new tools are supposed to be used. As things are presently going, with very little systematic experimentation of different approaches, no one will ever find out if there are practical ways of restructuring education around the use of the newer technologies.

Summary

Are educators technologically backwards? Not really. The simple fact of the matter is that there now is a high level of adoption of those few applications that are clearly cost-effective. The limited capability of current technology does not provide extensive opportunities to restructure education. The goal should be a more modest one of finding those few applications and leverage points where concentrated use can make a substantial difference, and implement policies that will help put such uses in place.

WHAT SHOULD THE ROLE OF GOVERNORS BE?

It is important for Governors to take a leadership position with respect to the use of technology in education. Governors can exert a lot of influence in the nature of the debate on how technology use in schools will be viewed -- both in their own state and nationally.

The tenor of this report has been to suggest that there is no crisis in the use of technology in schools -- only opportunity that has to first be

discovered. The only crisis in education is the need to improve the quality of education for all students. As such, Governors should continue to focus their leadership efforts on applying a wide variety of nontechnology approaches to improving the quality of education. If teacher quality problems are not solved, education will not get better no matter how many computers or films are purchased. In addition, the recent Carnegie Commission report has raised a number of serious concerns about the organization of curriculum at the secondary level that need to be addressed. At the same time, there is a need for Governors to assume a leadership role in focusing the use of technology to support improvement efforts in those instances where there is reason to believe there is a substantial payoff.

The use of technology in education is at a crossroads. There are several key issues to which Governors can bring leadership. The first is whether technology will continue to be viewed as a tool that we know how to use and whose implementation requires mass training to implement on as wide a scale as possible, or whether it will be viewed as a tool that we need to know a lot more about the conditions of its effectiveness. The second is whether the use of technology will be focused in ways that research has validated as effective in improving traditional educational outcomes, or will the technology movement continue as one that careens from one idea to another -- depending on what is in fashion at the moment. Will technology continue to operate on an advocacy basis or will it finally be put on a validated research basis? The third is whether we will continue to pretend that most technology is wonderful and act as though educators are too scared to use technology without massive amounts of advocacy and training, or will the right incentives be put in place for developing better forms of technology?

The fundamental leadership issue that the Governors can perform is to mobilize the enthusiasm that has excited many educators about the potential of technology, and redirect it in ways that will enhance education. The key tasks are to implement policies that:

- o Make sure that those uses of technology that have been demonstrated to be cost-effective are implemented in ways that they will be effective;
- o Establish key pilot experiments that will systematically test newer technologies that have high potential for being effective; and
- o Provide incentives to develop better technology.

The following are recommended policies for states to pursue to achieve the above goals. Governors can use these recommendations to initiate action they feel is appropriate and/or evaluate the policies already in place in their state.

Facilitating the Use of Existing Cost-Effective Capabilities

As previously discussed, the most cost-effective instructional applications of technology are automated drill and practice, particularly math, and telecommunicated instruction/distance learning. Simply recommending that schools use these tools will be inadequate due to structural problems

that exist. The problem with using **comprehensive automated drill and practice** is that while it is cost-effective relative to hiring additional personnel, minicomputer systems are too expensive for many districts and micro-based systems are not automated and may not be geared to the standardized test used in a particular state. This author knows of only one company that has the rights to automate the most popular micro-based drill and practice software. It is a small company that does not have the resources to serve national accounts or to customize for specific standardized test items.

> **Recommended policy**: States whose students take the same standardized test can pool their resources and either contract to develop their own automated drill and practice program or contract with a company that already has a drill and practice program to automate and customize it for them. The focus should initially be on math and then on aspects of language arts and vocabulary development. Arkansas has done some of its own development work and has achieved impressive gains at initial test sites. Such software also should be made to operate on a hard disc.

Another problem is that few districts have invested in a hard disc at the early grade levels that is needed to automate the management system (cost approximately $2,000 plus $150 per computer it is connected to), and few districts provide the extensive amount of computer time per child so the drill and practice will be effective.

> **Recommended policy**: States can provide funding to districts to establish hard disc capabilities if districts in return agree to identify a subgroup of students and provide them adequate time on the computer in accordance with the recommended guidelines in the research section of this paper to improve their performance prior to the eighth grade.

Telecommunicated instruction/distance learning. The primary obstacles to telecommunicated instruction are the cost of the communication system and classroom staffing requirements.

> **Recommended policy**: Make sure that the state education code permits such education to take place. Often a state's code requires a certified person to be present in all classes. This should be changed so that an aide or any adult, i.e., parent volunteer, can supervise the students at the remote learning sites while the lesson is going on.
>
> Study the technological alternatives for linking distance learning activities via existing state public communication systems such as those used by police and other emergency systems. Explore also some of the newer technologies such as fiber optic cable, as well as the ability to coordinate TV cable systems. Bring industry telecommunications experts in as members of any study group. In addition, a number of states such as Alaska have extensive experience with the technology and would be a good source of expertise.
>
> It may be necessary to provide some financing to help districts afford either transmitters, receivers, or communications costs.

Administrative applications. The market for student management software is evolving quite well, and the quality of the available software is good and getting better. There is, however, a problem with financial management software. Many states place responsibility for district financial management in the hands of a county office. The problem results from the flexibility given to county offices in most states to determine financial reporting requirements as part of their fiscal oversight responsibilities. Even where states have uniform accounting requirements, counties can often determine report formats. This can lead to enormous variations within states. For example, one county office in California requires its districts to enter certain information with red pencils. If a district enters it any other way they are reprimanded.

The allowance of variations in reporting requirements makes it difficult for the private sector to develop accounting software. A company that makes the enormous investment to develop financial management software often will find that even if it goes to the expense of customizing its program for a given state's accounting requirement, it still will not be able to market it statewide. Few companies can afford to develop a customized version for every county. The absence of a uniform market, even on the state level, means in effect that it is impossible for large companies to develop financial software. Nor do computer services provided by the county fill the gap. County computer services tend not to be highly integrated and automated -- resulting in extra work for schools. Counties do not have the large resources needed to develop a state-of-the-art computer services, and where counties do provide such service, they generally add to the district's work burden.

As a result, school districts usually have to choose among an inadequate county financial computerized system, performing the tasks manually, or developing their own software. At the same time, it is possible for the state to mandate uniform reporting procedures without diminishing the county's ability to exercise oversight responsibilities.

> **Recommended policy**: Develop statewide uniform reporting requirements -- both in terms of account structure as well as reporting formats. States also should consider working cooperatively to develop such standards to make it easier for vendors to develop and market software products.

Administrators often are unable to use administrative technology effectively. The problem is more complicated than simply being able to operate software, but has to do more with a total lack of training in how to use information from printouts, or other sources, to make decisions. Simply being familiar with what programs are available, or what the uses of the software are, it no substitute for hands-on generation of data and analysis of results.

> **Recommended policy**: Administrator training programs should offer two sets of experiences as part of the state certification requirements. In the first, administrators should learn how to use data bases and spreadsheets to set up systems to solve a variety of administrative situations. In the second, administration should use canned programs,

such as student scheduling software, to generate data for a simulated school and use the results from a series of simulation runs to develop optimal recommendations for a series of problems. To this author's knowledge no existing education administration program in the country presently has such requirements.

Some funding will have to be provided to colleges of education to enable them to get the equipment needed to implement such a program.

Piloting High Potential Technological Capabilities

There is a need to establish intensive, focused use pilots to test the cost-effectiveness of newer forms of technology. States can cooperate in testing various approaches and sharing the information gained and materials developed. Once knowledge of conditions of effectiveness is gained, then appropriate training programs can be developed.

Several states already have begun to conduct such projects with state funds. Arkansas is testing a variety of approaches for using reading and math drill and practice at the elementary level. Kentucky is testing the Write to Read program in the early primary grades. Minnesota also is funding a number of pilot projects. There are also pilot projects being reestablished with local and industry funds. The Higher Order Thinking Skills project is in twenty-one schools around the county. Plasencia school district in California is about to begin a school of the future project using satellite technology, which Apple Corporation is support a Classroom of the Future project where there is a computer on every student's desk. Cincinnati public schools have initiated a Computers Unlimited program, in which the entire high school curriculum will be rewritten to incorporate problem-solving activities on the computer.

States such as Minnesota have demonstrated that it is possible to satisfy political needs by making some state technology funds available on a widespread basis, while also allocating funds to a limited number of schools for targeted pilot experiments.

Recommended Policy: States that wish to provide funding for technology should allocate a significant percentage of that funding to more targeted uses that will provide adequate time to improve the learning of a limited targeted group of students in a particular subject area. In addition, such funding should be made contingent upon a given school's retraining its teachers with respect to related, but nontechnology-based, pedagogical techniques as well as creating more integrated process oriented forms of curricula. Specific minimum criteria as to the amount of time every student would be working at the computer should be specified. At least half the funds should be spent for experiments at the elementary level, and at least half the grants should be for non-drill and practice approaches or those that do not link directly to content most of the time.

Each grant should probably be on the order of $20,000 to $40,000 per school, with some follow-up funding available the second year.

Separate funds should be allocated for hiring teachers to develop curriculum before the project actually gets underway.

The experiments should be carefully evaluated with respect to traditional criteria over a two- to three-year period. Programs that use a nontraditional pedagogical approach should be examined for what happens when the students transition to regular programs.

Determination of success should be based on test scores on standardized instruments using accepted research procedures. Word processing or data base use should be tested on the basis of whether it improves the quality of writing or vocabulary development, while Higher Order Thinking Skills programs should be expected to transfer to some content area or measurable intellectual process.

State also should test several variations of a particular approach. For example, if a state wants to test intensive uses of technology to improve reading scores at the early primary grades, it would be best to test Write to Read versus the talking word processor versus language drill and practice programs versus a combination of the above. Testing only one model by itself is to put one's eggs in a single basket. In addition, if extensive funds are put into a single model then political pressure mounts to declare it a success and no real knowledge is gained. For example, while Arkansas is working primarily with drill and practice, different sites are using several different approaches to scheduling students and a clear pattern of the best approach has begun to emerge. In addition, a model should be tested at several sites at once to make sure observed gains are easy to replicate.

State should coordinate with types of pilots they wish to pursue in order to leverage the knowledge gained with available resources. Provisions for sharing the information gains also would be essential.

Helping Ensure That Evolving Capabilities Will be Transferred to Education

There is also a need to ensure that the quality of materials available continues to improve -- particularly software. Three types of policies are needed. The first is to increase the size of the market so that there is more incentive for publishers to develop better systems. The second is to provide more rational marketing procedures. The third is to consider funding the development of key types of software that have high cost-effectiveness potential.

Because of the limited size of the education market, most of the current software, even when it is good, covers only a single concept, requiring many discs, and is usually inconvenient to use, which further restricts the size of the market, which makes it difficult for vendors to invest in producing better software, et cetera. Policies are needed to break this cycle or everyone will lose.

Recommended policies: States can help generate a stable market by earmarking state funds for software acquisition. The pattern in states that provide technology funding is that most of it goes to the acquisition of hardware. Most district committees seem to want to buy as many computers as possible with little regard to software needs. States should set specific guidelines as to what percent of state technology funds should be allocated to software. Minnesota has gone a step farther and has a separate pot of state funds for software acquisition, which districts apply for on a per-pupil basis.

States that provide support for the acquisition of software should also use such funding to pressure the vendors into providing software in forms that are practical -- such as requiring that all software purchased with state funds districts be provided in a form that schools can easily put it on a hard disc or load multiple copies of the software into twelve machines with only a two to three times increase in the cost of the project. Drill and practice software should be provided with an automatic tracking system for hard disc use.

State should adopt a strong policy against software piracy along with appropriate sanctions against documented cases of abuse. Such policies should not, however, place restrictions on use that go beyond established case law.

Marketing represents the major component in the cost of software. Rather than engaging in expensive approaches to marketing software that parallel how books are sold, such costs can be substantially reduced by selling software in the same way that some companies market computers or educational film. Computers are generally sold at a state bid price with districts having option to order them from any local authorized dealer. Educational film is often distributed from the state department, which leases the right to either lend to, or make copies for, schools. Software could be sold the same way.

Recommended policies: States should negotiate, either separately or jointly, special discount prices for developers of highly rated software. Local computer stores could take over the responsibility of demonstrating the software, collecting the orders, and selling the product at the reduced rate. This would lower the marketing costs for publishers, while ensuring local computer stores of profits despite the special discounts for schools.

An alternative approach to reducing software marketing costs would be for state departments to negotiate special volume discounts and collect the orders for key pieces of widely used programs. Even better, states could negotiate lease licensing agreements to produce the copies for schools at a special agreed upon rate. There is a precedence wherein a number of states make and distribute copies of videotapes under special lease licensing agreements. This could be extended to software. This is the approach that Georgia is presently taking. It remains to be seen how successful Georgia will be in getting major publishing companies to participate but it is a high potential concept that will benefit both the publishers and schools. In some states it will be necessary to

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Marketing represents the major component in the cost of software. Rather than engaging in expensive approaches to marketing software that parallel how books are sold, such costs can be substantially reduced by selling software in the same way that some companies market computers or educational film. Computers are generally sold at a state bid price with districts having option to order them from any local authorized dealer. Educational film is often distributed from the state department, which leases the right to either lend to, or make copies for, schools. Software could be sold the same way.

Recommended policies: States should negotiate, either separately or jointly, special discount prices for developers of highly rated software. Local computer stores could take over the responsibility of demonstrating the software, collecting the orders, and selling the product at the reduced rate. This would lower the marketing costs for publishers, while ensuring local computer stores of profits despite the special discounts for schools.

An alternative approach to reducing software marketing costs would be for state departments to negotiate special volume discounts and collect the orders for key pieces of widely used programs. Even better, states could negotiate lease licensing agreements to produce the copies for schools at a special agreed upon rate. There is a precedence wherein a number of states make and distribute copies of videotapes under special lease licensing agreements. This could be extended to software. This is the approach that Georgia is presently taking. It remains to be seen how successful Georgia will be in getting major publishing companies to participate but it is a high potential concept that will benefit both the publishers and schools. In some states it will be necessary to

provide some protection to local computer stores and national mail order companies.

If the limited size of the market is one of the factors limiting the quality of the software at present, it will become even more of a problem in the future -- when even more sophisticated, complex, and potentially beneficial forms of systems can be envisioned. At the present time the National Science Foundation is focusing on developing the technologies of the future, such as artificial intelligence. This research is critical as natural market forces by themselves will not transfer the highly expensive artificial intelligence capabilities to educational applications.

At the same time there are some potentially cost-effective uses of existing technology that have not yet been developed -- and may not be. State can accelerate the development of some of these capabilities by cooperatively sharing development costs. The most likely candidate would be the automated dry lab system on interactive video systems, for either the junior high or senior high levels.

Recommended policies: States should explore joint funding of the development of a dry lab science course.

Governors should support continued funding for the National Science Foundation efforts in artificial intelligence applications to education.

States can help support the development of more sophisticated forms of software by funding several positions in their colleges of education to engaged in such activities. As colleges of education are presently being reduced in size across the country, few have the capability, will or vision to hire individuals capable of sophisticated forms of software research and development. There are probably fewer than five colleges of education in the United States with any faculty capable of engaging in artificial intelligence capabilities, let alone a team of such individuals along with fellowships for interested students.

General recommended policies: States can share information about the effective uses of technology. Such information should focus on narrowing the range of options schools need to consider rather than expanding them. For example, rather than listing all the available software in a particular subject area, states should provide information on which are the highest quality programs that meet particular state objectives. California is presently providing such information in their Technology in the Curriculum program. Project SEED is a consortium coordinated by North Carolina involving Alabama, Florida, Georgia, Louisiana, and South Carolina. This consortium shares the cost of conducting software evaluations and relating the evaluations to common state curriculum goals.

There is a need to make districts conscious of the benefits to targeting extensive computer use in areas where need is greatest and under conditions where research suggests that the computer activities are likely to be effective. A consortium of states should develop a

document that describes school- and districtwide planning techniques for phasing in targeted uses of technology.

States should share curricular materials that illustrate how to use a piece of software to synthesize concepts for a variety of fields.

While film and TV do not seem to produce the relative advantage that computers do, they do fulfill an important education function. Public television and education TV do perform worthy social functions and should be supported.

States can support the appropriate acquisition of technology by districts in the following four ways: gentle persuasion, grant programs, a cap on the percentage of district funds that can be allocated to maintenance and operation activities, thereby preserving sufficient capital funds so that districts can consider technology as an option, and support for the poorer districts that cannot generate sufficient capital funds through normal funding mechanisms. Since there is such diversity in school finance systems among states it is impossible to recommend which of the above should be considered in a given state. At the very least, however, a study should be made in states that have no state support for capital outlay expenditures as to whether the poorer districts are able to generate sufficient revenue to realistically consider technology as an alternative.

Colleges of education should be encouraged to provide preservice training in the use of technology. Such training, however, should be integrated into existing methods courses, rather than offered as separate, "add-on" courses. This will help professors and students understand the problems of integrating technology into the school's curriculum. States can help by providing needed capital equipment to colleges that can show how it will be used to upgrade programs.

What States Should Not be Doing

States should not be dispensing large amounts of moneys **primarily** for the purchase of hardware at the present time. Economic forces will continue to drive down the cost of hardware, and as the cost comes down schools will continue to increase their purchases. A substantial portion, preferably a majority, of any state funding should go into the purchase of software, the establishment of intensive use pilot projects, possible contracting for automated drill and practice software, communication linkages, and perhaps for support several research and development positions in colleges of education.

State should not establish massive training programs for most teachers. Most such training will be ineffective in the absence of better information on the conditions of the effectiveness of newer forms of technology.

States should not establish extensive computer literacy mandates, and should think twice about establishing any at all. Such mandates drain resources from improving the ongoing educational program and do not enhance opportunity. If states want to mandate a course in literacy, it probably should be done as a semester course at the junior high or middle school

level. (States that already have established mandates for the high school level may want to consider moving them down to the junior high level once students who did not get exposed to computers at the junior high level have passed through the system.) The high school years should be reserved for developing advanced types of skills rather than exposure to computers. (Eventually it would be hoped that a literacy activity at the junior high level could be replaced with a program to develop thinking skills.) It would, however, be appropriate to mandate that high schools offer courses in programming that are made available to all without prerequisites -- but not to require all students to take such a course.

When states do decide to mandate computer literacy, it would be better to leave the definition of the curriculum up to each individual district as opposed to mandating a "model" curriculum or specific skills such as keyboarding.[16] Definitions of concepts and ideal practices are changing too rapidly.

According to the June 4, 1986, issue of Education Computer News, the National Commission for Employment Policy has adopted the position that a nationally standardized definition of computer literacy or a requirement that all high school graduates be computer literate would be ill advised. This is one of the first national organizations to recognize that computer literacy is becoming obsolete as a concept.

States should not be establishing their own independent procedures to evaluate and test software but should help disseminate information based on existing published sources, or conduct such evaluations jointly with other states, such as the previously mentioned project SEED.

State software recommendations should be advisory only. States should not establish an approval mechanism for software as they do for textbooks and limit purchases with state funds only to items on that list. There are too many different rapidly changing software products. In addition, states should not require textbook publishers to produce software to get their texts on the state approval list. This will only result in the production of a lot of low quality software.

States should not allow districts to apply capital outlay funds to maintenance and operation activities, as that will make it very difficult for districts to reserve funds for the purchase of technology. The vast majority of states currently prohibit such transfers but some permit it.

ENDNOTES

1. A recent conversation with an NSF official. There had recently been a sharp drop in the number of students entering the field of science that could ultimately create a shortage in the number of scientists.

2. Officials of Kurweil Voice Systems were quoted in a recent article in Infoworld as having a 1,000-word speech to text system that runs on an IBM PC for $7,500, with a 10,000-word system to be available by early 1987. Once products and a market start to appear it generally takes only about four years for the technology to become highly cost-effective for mass use.

3. Many in the field of using computers to develop thinking skills argue that the benefits are either likely to be unmeasurable, or that such use provides inherent benefits that should not be subject to testing. While there is some truth to these claims, if everyone goes forth believing that benefits cannot and/or should not be measured then no one will attempt to develop programs that will in fact produce such gains, which ultimately will result in sloppy programs that have very low level of acceptance among practitioners. In fact, the ideal should be to aspire to develop thinking programs that not only produce gains in forms of thinking that can be measured, but that also produce gains that transfer into other measurable areas. This is extremely difficult to do -- but probably not impossible. Teri Rosegrant has used her Talking Word Processor to enhance vocabulary skills of preschool learning disabled students. Four out of the five Higher Order Thinking project schools have reported their testing results have found much higher than expected gains on standardized basic skill tests.

4. This section is based on two papers that have not yet been published. The findings on the research on computers is a summary of the conclusions from a paper presented by this author at the 1986 meeting on the American Educational Research Association. The conclusions about video are from a paper by Jerome Johnston of the Institute of Social Research at the University of Michigan, as relayed to this author in a phone conversation. The findings on distance learning are from a series of presentations at conferences where it was demonstrated that students in this program did as well as under conventional instruction.

5. The most widely cited meta-analyses are those conducted by James Kulik and his associates at the University of Michigan. Generally these studies report very substantial gains from the use of computers. At the same time, these studies suffer from the types of shortcomings listed in the text and by themselves do not prove a relative advantage from computer use.

6. One of the problems of the Levin, Glass, and Meister study was that it included results from initial computer use activities before the program was fully implemented, and thereby generated different results than the reanalysis conducted by the Educational Testing Service, which was the prime evaluator of the project.

7. The Los Angeles systematic variation experiments tested a wide variety of approaches to providing drill and practice and then compared the results. The Arkansas systematic variation experiments (Project Impact, McDermott, 1986) confirmed that daily use is most effective on an ongoing basis, but the study was not as clear on the optimal time per day, although most sites used the computer twelve to twenty minutes per day.

8. Reviews of the research on the effectiveness of Logo by Howell (1985) and Clements (1985) did not find and transfer from its use, and whatever effects were produced could be generated a lot more simply with other techniques. Bangert-Drowns, J. Kulik, and C. Kulik (1985) concluded in their meta-analysis that integrating programming and simulations into courses did not enhance learning.

9. Several studies have found that the use of word processing can increase the motivation to write and the amount of revision that students do, but to this author's knowledge no one has shown that there has been a resultant increase in the quality of writing. Indeed, a soon to be completed dissertation by Virginia Juettner of the University of Arizona, failed to find writing improvements in the group she studied despite the existence of more enthusiasm and revision. At the same time, it is highly probable that under the right conditions word processing can be made to enhance writing and vocabulary under more extensive and better thought out conditions of use.

10. Just as it was once argued that television in the home will create a learning revolution, it has been suggested that a computer in the home will reduce the need for teachers, and possibly even eliminate the need for schools. A recent study by Robert Hess of Stanford University found that young children who had computers at home did not show as great a gain as when computers were used both in the school and home, and home activities were geared to what was going on in school.

11. As an add-on, technology must produce very substantial gains in order to be considered.

12. There is, of course, a compromise between using all funding either for providing widespread exposure to computer activities and those that are targeted with intensive use. The problem becomes one that, in most districts, the implementation plans always call for such wide distribution of general exposure activities that no funds are ever likely to be available for targeted use under realistic budgeting constraints prior to the next decade. A prudent plan would call for some limited forms of general exposure with remaining funds concentrated in a targeted way.

13. Three years ago, this author called several of the major drill and practice companies and begged them to consider putting out hard disk versions of their systems. At the time, they indicated that there was no market for such a system (which I knew not to be true because I had encountered many districts that were actively seeking such a product) and it would not be practical because elementary schools did not have hard discs. Three years later these companies still do not have such versions available, the hard disc vendor who put his or her eggs in the education market is being forced to lay off workers, and schools are being deprived of an opportunity to have low-cost automated drill and practice systems.

14. One continues to find studies and reports that conclude after the fact that a particular use of computers that had been promoted as being essential/wonderful was more difficult to implement and more difficult for students than had been anticipated. For example, it now appears that the learning of programming is far more complex than had been previously assumed and concern is being expressed that many students exposed to its complexity before they were developmentally ready for it, or before they had some references that would enable them to see a value in that activity, actually ended up dissuaded that they could ever be good at it or interested in it. The latest fashion is word processing as a tool

(which means typing a bad composition onto the computer and printing it out). Occasional exposure to word processing is supposed to help kids become better writers. Once again, it is not that simple. An unpublished study by Colette Daiute reportedly found that it took a whole year before junior high children could write as well on the computer as they could with pencil and paper.

As the cycles of advocacy pass, and it is realized that things did not work the way they were expected to, the tragedy is that the outcome could easily have been anticipated and avoided.

15. By going slow in developing and testing the Higher Order Thinking Skills project, this author was able to discover many consequences of computer use that had never been reported in the literature, and was able to build training and curriculum materials around these discoveries. Indeed, few of our initial expectations about the way that things would probably work ended up being true. There are many other interesting discoveries to be made by others if they are willing to engage in a piloting process.

16. While business educators often claim that there is research that indicates that if students learn to keyboard incorrectly when they first start to use the keys, they will get into bad habits that will be hard to remediate later. In the past year, I have asked three state directors of business education to provide me with research to substantiate their claims. One never responded, one indicated that she had not been able to find any, and the third found one study (of very poor quality) that found that early keyboarding students did less well in typing speed at the senior high level than those learning it for the first time. Other than saying that students who are really good writers and who are ready to write a lot should be given some keyboarding instruction, there is no reason to believe that it is important to require all students to learn it before using the computer for educational purposes.

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PART THREE: Additional Resources

HIGHLIGHTS OF STATE PROGRAMS

The following examples are not intended to describe everything that is happening around the country, but to give examples of the different approaches states are taking.

Examples of cooperative programs among states:

a. SEED: Six Southeastern states have established a cooperative program to evaluate computer software. They are Alabama, Florida, Georgia, Louisiana, North Carolina, and South Carolina. By working together, the states will avoid duplicative efforts while having access to information developed in each of the states.

b. Agency for Instructional Technology: Since 1970, states have cooperated to develop twenty-one instructional television, video and computer products, at a cost of $24,600,000. All fifty states and several Canadian provinces have participated, though most were not involved in each project. States which help support a production receive unlimited duplication and reproduction rights for the life of the material. Overall, each state has provided about two percent of the costs for the projects in which they participated.

c. Satellite programs: Alaska, New York, North Carolina, Oklahoma, Texas, and Utah are learning about each other's efforts to use satellite transmission and cable television to provide courses in remote areas. Several other states have expressed interest in working with this group. No formalized consortium has been established.

Alaska: With major federal assistance, the state has established a satellite television network (LEARN-ALASKA) which provides a vast array of programs to students in isolated villages. The state has also organized audio-conferencing capabilities linking schools throughout the state.

Arkansas: Project IMPAC - Arkansas established a private non-profit organization which negotiated a state-wide contract for the purchase of computers. This contract permits schools to receive a substantial discount on computer purchase. The state also has conducted experiments of different kinds of computers. This led to the conclusion that over a three-year period, a slightly more expensive computer was the more economical purchase because it required less maintenance than the lower-initial cost computer.

California: California has established teacher centers throughout the state from which training and software review is available. The centers are administered by regional policy boards with assistance from the state. California also spent $2.5 million on a 1,400-page guide describing how to integrate the best of video and microcomputer software into the K-12 curriculum. The project focuses on mathematics, language arts, science and history-social science. Two additional technology programs in the curriculum guides are being

prepared for fine arts and foreign languages. Over the last three years, $39 million has been distributed on a competitive basis to assist adoption or expansion of technology programs at the school site. During the first two rounds of funding, 70 percent of the money was spent to purchase microcomputers. In 1985, every school received a video cassette recorder through funds provided by the state. The state put out a competitive bid and selected the best one.

Maryland: Maryland has established an educational technology network that provides assistance to school districts wishing to purchase and use emerging technology. The state is sharing facilities with its public television station and has established demonstration sites for different applications of technology.

Minnesota: Minnesota uses incentives to help each district to develop programs to use computers and other advanced technology. Each district is encouraged to establish its own plan for using technology. The plan must show the district will provide access to women, minorities and the handicapped. It must also show how training will be conducted and explain ways faculty and community members are involved in creation of the plan. Once the state department of education approves the plan, the school district receives funds for training and purchase of approved software. The state has also funded fifteen technology demonstration sites that are experimenting with various combinations of computer, videodisc, cable television, et cetera. The state does not require that any particular course be taught about technology, but encourages use of machines throughout the curriculum.

Missouri: The state recently allocated $2.4 million to help school districts purchase microcomputers, software and training for their staff. Schools received the funds on a 50 percent match basis. (For every state dollar, the local district had to put up a dollar.) School districts decided how to spend the money within general guidelines established by the state. Virtually all school districts participated in the program.

New York: The state has established an elaborate series of programs to develop, coordinate and expand technological applications in the state's educational institutions. New York has established a variety of cooperative activities with private sector vendors. For the last three years, the state has appropriated funds to help school districts purchase computer hardware and software on a need basis. School districts in low-income areas receive extra assistance. During the current year, the state has appropriated $21 million dollars for this purpose. There are now more than 100,000 computers in the state's public and nonpublic schools. The state is also experimenting with interactive television and telecommunications programs to provide courses to rural students.

Tennessee: The state allocated $9 million to support its "Computer Skills Next" program. The state board of education requires that each

seventh and eighth grade student receive fifteen hours of computer literacy instruction (thirty hours total). The state department of education wrote the curriculum for the thirty hours and provided five-day training sessions for teachers offering the instruction. The state developed a bid for computer hardware, selected a vendor, and provided funds so that there was one computer for every thirty seventh and eighth graders. More than 7,000 computers were purchased under the statewide bid program. The state also provided $500 to each of the 600 participating schools to purchase instructional software.

Texas: The state has established programs in which rural school districts receive specialized courses via television and satellite transmission. The courses are produced by a private corporation under contract to intermediate units. The state has also established a cooperative program with the Texas School Board Association in which new materials are being developed. Texas requires that all seventh or eighth graders take a course in computer literacy.

Virginia: The state has established several demonstration schools to test different kinds of education technology. One of the schools is open to students from several districts and functions as a magnet school. Another of the demonstration programs serves not only its own students but young people attending other schools miles away. These distant students are served by an experiment in televised courses.

ADDITIONAL SOURCES

The reader who wishes additional research information and resource material is referred to the sources listed below. The clearinghouse is funded and coordinated under the auspices of the U.S. Department of Education's Office of Educational Research and Improvement.

Educational Technology Center (ETC)

The Educational Technology Center seeks to find ways of using the computer and other information technologies to teach science, mathematics, and computing more effectively. Reflecting ETC's commitment to improved instruction, most of the center's projects rely on clinical studies of learning and on teaching experiments that make use of software designed specifically to overcome identified impediments to learning. A smaller number of projects are being conducted to explore the broader educational potential of emerging technologies.

ETC
Gutman Library
Harvard Graduate School of Education
6 Appian Way
Cambridge, MA 02138
(617) 495-9373